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ENERGY
FOR PENNSYLVANIA

An Action Plan
for
Energy Management in the
Commonwealth of Pennsylvania

to GOVERNOR MILTON J. SHAPP

by the GOVERNOR'S SCIENCE ADVISORY COMMITTEE

April 1974

ENERGY FOR PENNSYLVANIA:
A PLAN FOR ACTION

Submitted to

Governor Milton J. Shapp

by

The Governor's Science Advisory Committee

April 1974

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PROLOGUE

Governor Milton J. Shapp met with the Governor's Science Advisory Committee (GSAC) early in 1972 and charged them with the responsibility of recommending to him ways of meeting an anticipated energy deficit in Pennsylvania. Policy considerations and an understanding of Pennsylvania's unique role in the energy economy of the United States were to be a part of the GSAC study.

This report on the interaction of technology and the three E's - Energy, Environment, and Economy - is based on work during the past year of a special panel of the Governor's Science Advisory Committee (GSAC). It endeavors to identify significant technological trends and options with special relevance to Pennsylvania.

The Energy Panel's findings were thoroughly discussed both in their deliberations and with the entire Governor's Science Advisory Committee. There is agreement on the urgency and importance to Pennsylvania of proper development of nuclear power and of the three C's - Conservation of energy, Conversion to Coal (in the 70's), and Conversion of Coal to sulfur-free gas and oil (for the 80's).

Governor Shapp, aware of the need for urgency, recently created an Energy Task Force comprised of the heads of the state agencies responsible for Commonwealth programs. The need for wise energy use, an adequate energy supply, a quality environment, and a healthy economy demands focused attention on energy developments during the critical years of the mid-70's.

Currently, GSAC panels are preparing reports scheduled for early 1974 on Criteria for Power Plant and Transmission Line Siting in Pennsylvania and on Pennsylvania's Opportunities for Transportation Developments.

The best judgments of informed Pennsylvanians are needed to guide energy management in Pennsylvania and we believe that this report can contribute to such considerations.

ACKNOWLEDGEMENT

The work of the Energy Management Panel was greatly enhanced by the personal interest of Governor Shapp and by the invaluable support provided by Mr. Walter Arader, Secretary of Commerce, and by members of his staff, including especially Mr. Robert D. Laughlin, Director, Bureau of Scientific & Technological Development, Mr. I. J. Sobel, Program Manager, and by Mr. Albert E. Smigel, Director, Bureau of Statistics, Research and Planning. We were greatly aided by the interest of Mr. A. Edward Simon, Director of the Office of State Planning and Development, and the personal participation of Mr. Robert Sidman, Coordinator and Mr. Frederick D. Grundeman, Staff Consultant of that office. Valuable information and comments were made by other state agencies, especially by Dr. Maurice Goddard, Secretary, Department of Environmental Resources, and by Mr. Wesley E. Gilbertson, Dr. Arthur Socolow, Mr. Clifford H. McConnell, and others of the DER staff.

The evident interest of members of the legislature in technological and other considerations affecting Pennsylvania's energy needs and environment was also a spur to the work of this panel.

The panel wished to acknowledge, with grateful appreciation, the help of many others who provided input to this report. Although much of the material provided is not directly referenced, it significantly influenced the assessment of options and the recommendations presented herein.

ENERGY FOR PENNSYLVANIA:

A PLAN FOR ACTION

I. SUMMARY AND RECOMMENDATIONS

PENNSYLVANIA'S ENERGY NEEDS

THE GOOD NEWS

PENNSYLVANIA'S FUEL DEMANDS

Overall, Pennsylvania

- --Uses more coal (38% of Pennsylvania fuel needs) than the U. S. average (17% of U. S. use).

- --Uses less natural gas (17% of Pennsylvania needs) than the U. S. average (27% of U. S. fuels).

Pennsylvania Industry

- --Uses much coal (55% of its fuel needs) and little petroleum (17% of needs).

Pennsylvania Utilities

- --Currently generate nearly two-thirds of their electricity from coal.

- --On completion of 9 new plants (by 1981?) will DOUBLE CAPACITY with 1/3 from nuclear fuels and less than 1/6 from petroleum.

PENNSYLVANIA'S ENVIRONMENT

- --Primary air standards can be met with minor variances for short periods.

- --Modern machinery and techniques for strip mining and land restoration provide both excellent environmental protection and low cost coal.

THE BAD NEWS

IMPACT OF THE SHORTAGE

--75% of Pennsylvania residential and commercial heating is supplied by scarce oil and natural gas; transportation is almost completely dependent on scarce petroleum.

--Apportioning fuels will mean cutbacks in heating and air conditioning, auto and air travel, and industrial operations (affecting jobs and incomes).

BARRIERS TO AN INCREASED FUEL SUPPLY

--There exist delays in the construction of the 6 planned nuclear power plants scheduled by 1981.

--The coal industry is in decline and the scarcity of capital, skilled manpower, and equipment slows its revival.

--Greater use of coal in the 70's may require some temporary variances in meeting primary air quality standards and my be limited unless application of secondary air standards is somewhat delayed.

--Pennsylvania is short of facilities to refine petroleum and to transport and store petroleum and natural gas.

--Federal import, pricing, and environmental regulations discourage development of domestic petroleum and natural gas and refineries.

--The logistics of importing oil requires huge tankers and major off-shore deep-water ports, which do not now exist.

BACKGROUND: GOALS AND OPTIONS

--Energy will no longer be abundant and cheap. Conservation must be the bedrock of the new energy management policy. Improved technology and sound public policy are essential.

--Coal is a key to U. S. self sufficiency in energy. Nuclear power is another. Pennsylvania has much coal and is a leader in the nuclear industry.

--Pennsylvania can move into the era of modern coal technology wherein coal will be transformed into clean, readily-available fuels.

--Development of new technology takes time. Till then, Pennsylvania must use the best available coal and nuclear technology and environmental criteria.

COMMONWEALTH ACTION: A PENNSYLVANIA ENERGY MANAGEMENT STRATEGY

To meet the energy shortages of the 70's and to benefit from new developments for the 80's, the Commonwealth must establish:

--Public Policies - based on on-going knowledge and understanding of changing developments and options.

--A Plan for the 70's - using incentives and controls and the best current technology to reduce energy demands and to increase the supply in the shortages of the 70's.

--Action for the 80's - with early participation of Pennsylvania institutions in imminent Federal and corporate developments of new clean energy technologies for the 80's.

The Governor's Science Advisory Committee and its Energy Management Panel recommend actions to meet these three needs. Accordingly, five recommendations for executive and/or legislative action are presented (pp. 7-9) with references to specific goals and approaches (pp. 4-6).

GOALS AND APPROACHES*

1. A COMMONWEALTH ENERGY MANAGEMENT STRATEGY

The Commonwealth working through and supporting the state's action agencies should, for example:

--Expedite policy, planning, and decision making on all energy questions while meeting primary environmental and economic goals.

--Participate in setting Federal energy and environmental policies.

--Establish contingency plans for handling fuel shortages.

--Promote the conservation and wise use of energy.

--Submit to the Dederal government an attainable schedule for secondary environmental standards to permit use of coal in the shortages of the 70's.

--Intensify and expedite the review of applications for mining operations, power plants, refineries, and other energy facilities.

--Promote the collection and use of solid wastes for direct or indirect use as fuels.

--Provide adequate staff so that the Council(s) and the state agencies can make policy decisions and take prompt action on the basis of pertinent data and analysis of on-going energy developments.

2. ENERGY FOR THE 70'S

Early and wide use must be made of best available technologies to assure health, comfort, and jobs for Pennsylvanians at acceptable environmental and economic costs. Such a Pennsylvania program must promote:

WISE USE AND CONSERVATION OF ENERGY

--Provide public information and education for more effective use of energy.

--Modify building codes and design practices to encourage application of current technology to conserve energy.

*See Section III for detailed discussion.

- --Keep and strengthen rail transportation for piggyback and other freight in Pennsylvania.

- --Strengthen mass transportation and promote its use.

- --Examine a modified rate structure for use of electricity.

- --Plan for long-term conservation of petroleum.

EFFECTIVE USE OF CURRENT NUCLEAR AND COAL TECHNOLOGIES

- --Expedite construction of nuclear power plants with proper safety features.

- --Convert to coal for producing power.

- --Increase coal production; lower sulfur first; train coal mining manpower.

- --Reduce sulfur content in bituminous coal by mechanical means and use more low-sulfur anthracite when practicable.

- --Use combustion and post-combustion processes for sulfur removal or dispersal, as determined to be effective including; addition of lime or dolomite to coal; stack gas scrubbing; and/or use of tall stacks.

- --Use available technologies to meet primary air standards, employing temporary minor variances if necessary to meet critical energy shortages, with monitoring, strict controls, and a reserve of clean fuels for use during an atmospheric inversion.

EXPANSION OF PENNSYLVANIA'S ENERGY SUPPLY AND DISTRIBUTION SYSTEMS

- --Develop power plant and transmission line siting criteria for developments till the year 2000 and beyond.

- --Create climate for effective financing of construction of refineries and oil and gas storage and other energy and fuel distribution systems.

- --Use wood and urban, agricultural, and industrial wastes as energy sources were practicable.

3. CLEAN ENERGY FOR THE 80'S: LEADERSHIP IN NEW TECHNOLOGY

Aggressive Pennsylvania participation is required NOW in vigorous development of new clean energy options for the 80's. Such a Pennsylvania program should promote:

EFFICIENT ENERGY USE:

--New means for energy conservation and efficient use.

--Means to convert wastes to fuel or direct heat, with enabling legislation and incentives to promote waste collection and use.

--Develop mass transit and rail facilities with incentives for their use.

MODERN COAL AND NUCLEAR TECHNOLOGY

--Intensify the detailed geologic and mapping data gathering of Pennsylvania's coal, oil, and gas reserves.

--Develop improved technologies for mining, cleaning, transportation and burning of coal and subsequent disposal of wastes.

--Support conversion of coal to oil and gas: accelerate research and development, identify and dedicate appropriate coal fields, and provide incentives and financial help for implementation.

--Encourage development of nuclear technology with emphasis on safety and disposal of heat and wastes.

--Stimulate growth of energy equipment manufacturing and engineering industries in Pennsylvania.

A DOMESTIC PETROLEUM SUPPLY

--Develop technical and economic means to get more oil and gas from Pennsylvania fields.

--Consider drilling for gas in Lake Erie.

PROTECTION OF ENVIRONMENT AND HEALTH

--Encourage Federal and Private sector research, with participation of Pennsylvania institutions on the fate of pollutants from combustion processes, on their effects on human health, materials, urban and rural environments, on new technologies for coal mining, and on energy production and use which maximize the protection of human health and the environment.

RECOMMENDATIONS

To achieve these goals, thoughtful, vigorous, and sustained action is needed by the Commonwealth, its citizens, and its institutions. With this in mind, GSAC submits the recommendations presented below.

1. PUBLIC POLICY: AN OVERRIDING NEED

TARGET: Public policies must assure the delivery and wise use of energy by means consistent with environmental and economic goals.

● RECOMMENDATION: COMMONWEALTH ENERGY POLICY COUNCIL(S)

The executive and legislative branches should establish (jointly or separately) Energy Policy Council(s) to expedite policy and decision making and to monitor and support implementation of the Commonwealth's energy policies by the state's action agencies.

(Specific tasks are suggested on page 4)

ACTION: The Governor should issue executive directives and recommend that the legislature consider appropriate actions and legislation.

● RECOMMENDATION: ADEQUATE STAFF FOR ENERGY DATA ANALYSIS AND DECISION MAKING

The Energy Policy Council(s) and the state's action agencies should be provided with staff adequate to provide data, analytic services, and project review on energy and environment issues.

ACTION: The appropriate agencies and the Office os State Planning and Development should formulate recommendations for the necessary staff and budgets than submit them to the Governor.

2. ENERGY NEEDS IN THE 70'S

TARGET: To avert crises the Commonwealth can use legal and economic incentives and controls to reduce energy demands and to increase the energy supply. The Commonwealth should promote the use of the best available technology and environmental criteria to achieve:

--Wise Use and Conservation of Energy

--Effective Use of Current Nuclear and Coal Technologies

--Expansion of Pennsylvania's Energy Supply and Distribution Systems

(Specific approaches to these ends are suggested on pages 4 and 5.)

● RECOMMENDATION: COORDINATED COMMONWEALTH ENERGY PROGRAMS

Under the guidance of the Energy Policy Council(s) (recommended above) the appropriate state agencies should coordinate their actions with Pennsylvania industries, universities and with Federal agencies, to achieve the above targets.

ACTION: The Energy Policy Council(s) in concert with the Public Utilities Commission, the Department of Environmental Resources, the Department of Commerce, the Department of Transportation, the Office of State Planning and Development, and other state agencies should investigate current programs, resources, and activities and formulate action programs.

● RECOMMENDATION: ADDITIONAL OPTIONS

The Governor should consider for further action:

Use of incentives to encourage energy conservation and equipment for improvement of environment.

Means to help utilities finance energy producing facilities.

Encouragement of deep-well drilling for oil and gas in Pennsylvania.

Means to develop deep-water ports for Pennsylvania's use.

Support of national policy for off-shore drilling on Atlantic Shelf and Gulf and Pacific coasts, Alaskan oil development, and possible use of western oil shale for increased domestic supply of natural gas and petroleum

ACTION: The Governor should direct immediate consideration of the foregoing and recommendations as appropriate by: The Commonwealth's Energy Policy Council(s), The Department of Environmental Resources, Environmental Quality Board and Citizens Advisory Council, the Department of Commerce, Office of State Planning and Development's State Planning Board, and other appropriate State agencies and private organizations and institutions.

3. NEW ENERGY OPPORTUNITIES FOR THE 80'S

Developments in converting coal to clean burning oil or gas will create new industries and transform existing ones. These will move ahead immediately, with increases in Federal energy research funds of $100 million this year and $2 billion per year for the next five years, as well as major new funding in the private sector.

Pennsylvania, favored with abundant coal, leadership in supplying nuclear plants, research centers in coal and nuclear science, many engineering and processing firms, and a power-dependent industry, stands to reap major benefits in the new coal and nuclear era ahead.

TARGET: The Commonwealth should promote early participation of Pennsylvania's industry and universities in new developments of:

--Efficient Energy Use

--Modern Coal and Nuclear Technologies

--A Domestic Petroleum Supply

--Protection of Environment and Health

(Specific approaches to these ends are suggested on page)

● RECOMMENDATION: ENERGY RESEARCH AND DEVELOPMENT

The legislature should provide funds to the Pennsylvania Science and Engineering Foundation (PSEF) to seed research and development in Pennsylvania with Federal and private funding of modern energy technologies listed above. Funding at a scale of at least one million dollars per year for an estimated five years is required.

ACTION: The Governor should recommend and the legislature should appropriate an additional $1 million for PSEF for fiscal year 1973-74.

II. The Energy-Environment Predicament

The problems of meeting the energy needs of Pennsylvania as well as the rest of the nation will exist for many years ahead. Three important factors contribute to the problems.

1. Growth in energy demands brought about by increasing per capita demands for energy (from 252 million Btu/per person in 1962 to 340 million Btu/per person in 1972, an increase of 35%) and by the increasing size of the population.

2. Rapid establishment of severe environmental controls on discharge of pollutants to the atmosphere and to our rivers and streams so as to provide a more acceptable environment and a lesser and better controlled disturbance of nature's ecological balance.

3. Inadequacy of facilities to produce fuels of the quality necessary to meet the new environmental standards.

The problems in no way have to do with adequacy of resources for it can be shown that adequate resources exist for many centuries ahead. However, some of these resources are in forms which must be processed to remove pollutants if they are to meet the new environmental requirements; some of the resources are in forms more costly to extract from the ground than those we are using currently.

It is becoming increasingly clear that the cost of energy will rise as we have to resort to using fossil fuels which are more difficult to extract from the ground or which require extensive processing to make them useful in terms of our environmental requirements. The extent to which particular approaches will succeed will depend upon their relative costs.

The market place should be quite capable of providing incentives to convert these energy resources into available supplies to consumers, but as R. L. Gordon points out "the U. S. government has accomplished the unbelievable feat of blocking the operation of all the major energy markets. Gas supply has been hindered by field price controls. We have had an oil policy that purports to limit imports to encourage domestic output but is so designed in practice that it generates the worst of all possible worlds. A tacit policy of increasing quotas to hold down domestic energy prices removes any price incentives to domestic producers. At the same time, the reluctance with which quotas are raised can lead to strains on energy supply at least until the quotas are adjusted. We have imposed a mass of regulations on coal production and consumption that similarly retard that fuel's contribution to energy supplies. To this must be added the construction and regulatory problems with nuclear plants and the barriers to the Alaskan pipeline and offshore drilling for oil and gas produced by environmental concerns." (1)

It is quite evident that we urgently need a better thought-out national energy-environment policy which will lead to incentives for more effective utilization of energy, for development of more facilities to fulfill the nation's needs, and for meeting the nation's environmental objectives in a reasonable and acceptable time frame. These incentives must be coordinated to be effective. If we continue to discourage all forms of energy supply, energy problems will in truth reach crisis proportions.

Despite the lack of a coordinated national energy-environment policy, there are a number of steps that the state can take to help the situation within its own borders as well as within the nation as a whole. These are presented in the recommendations. While only a few of these appear to have quick-term impacts, all of the steps, regardless of whether they lead to short-term or long-term solutions, must be started now if practical solutions are to be achieved to avert a succession of serious crises.

Energy is essential to a dynamic economy for both the state and the nation. Today both are relying increasingly on foreign oil as a source of clean energy. But the resulting imbalance in payments and the nation's vulnerability to foreign influences in order to assure a continuing clean fuel supply could lead to economic and social problems of catastrophic proportions. Thus the United States cannot long afford to rely on foreign sources for clean fuel supplies, nor in the long-term does it need to do so if appropriate use is made of its large coal reserves and its nuclear fuels.

Pennsylvania has been a leader both in the production and use of coal and in the development and use of nuclear power. Pennsylvania's coal industry is in trouble, however, because much of its coal has a high-sulfur content, and its use produces effluents which do not meet desired environmental requirements. But Pennsylvania has the opportunity to correct this situation by taking the lead in moving into the era of modern coal technology whereby coal can be transformed to low-sulfur oil or gas to meet domestic and industrial needs. It has abundant coal for this purpose both to supply internal needs and to export.

Since the development of modern coal technology takes time, decisive action is needed now by the Commonwealth's legislative and executive branches to take advantage of the opportunities it will provide. The conversion of coal to the higher energy forms of oil, gas, and other new developments in the production and use of energy will create new industries, and greatly alter the practice of existing ones within the next decade. In the interim, Pennsylvania must use the best available technology to fulfill its energy needs with minimum insult to the environment. Appropriate action is also needed now to help assure continuing availability of clean fuels and appropriate public policies to govern their use in the immediate years ahead.

III. Discussion of Goals and Approaches

Section I summarizes recommendations which GSAC feels should be aggressively implemented now by the Commonwealth and the goals and approaches on which the recommendations are based. This section discusses each of these goals and the suggested approaches for meeting them and indicates when and what results might be expected. Each suggestion is identified with the time period in which benefits might be expected. Three categories are used: Short-Term for approaches which can produce results between 1973 and 1978; Medium-Term for approaches which are needed to produce benefits in the period 1978 to 1985; and Long-Term for those which syould produce benefits after 1985.

A. A Commonwealth Energy Management Strategy

To meet the energy shortages of the 70's and to benefit from new developments for the 80's, the Commonwealth must establish means for developing public policies based on on-going knowledge and understanding of changing developments and options. This effort will require the coordinated action of the state's governmental agencies. It is believed that, to accomplish this coordination, the executive and legislative branches of the state government should establish (jointly or separately) Energy Policy Council(s) to develop coordinated energy-environment strategies, to streamline policy and decision making, and to monitor and support implementation of the Commonwealth's energy policies. The Commonwealth's Energy Policy Council(s) working with and through the state's agencies should include among its activities the following actions.

1. Expedite Policy, Planning, and Decision-Making on Energy-Environment Questions (Short-Term)

The Commonwealth faces many conflicting requirements in discharging its responsibilities to assure for its citizens both an acceptably clean environment and adequate energy. Effective progress in satisfying both needs requires dovetailing of goals and capabilities in both areas.

This effort will require careful planning using best available estimates of existing situations and expected developments. Such plans should serve as the basis for developing consistent policies and for facilitating decision-making. Planning should be based on schedules which are attainable and are consistent with a balanced well-being of present and future citizens of the Commonwealth. Alternative plans based on various premises regarding future situations should also be developed to help expedite decision making and reorientation of policies when and if conditions change.

The Energy Policy Council(s) in working with state agencies should give high priority to such planning as the basis for coordinating and expediting policy and decision making. In their efforts to provide a clean environment and adequate energy, state agencies must work with integrated plans and coordinated time scales for best effectiveness.

2. Participate in Setting Federal Policies (Short-Term)

The Commonwealth of Pennsylvania should make provisions for maintaining an active awareness of federal energy and environmental policies under consideration; for evaluating the effects that such policies might have upon the energy situation in Pennsylvania; and for taking steps to see that the Commonwealth's interests are reflected in laws and regulations promulgated by the federal government.

3. Establish Contingency Plans for Handling Fuel Shortages (Short-Term)

The Commonwealth should study the question of what happens if and when various shortages materialize. The study should include developing bases for the establishment of priorities for energy rationing, the implementation or administration of controlled distribution of energy, and the impact of alternative policies.

4. Promote the Conservation and Wise Use of Energy (Short-Term)

Low-cost energy has been so readily available that too many of us have become indifferent about how we use it. But this is a luxury we can no longer afford. We must begin now to conserve energy both by adjusting our demands and by improving the efficiency with which we use energy. The actions needed to promote the conservation and wise use of energy must be considered as part of the Commonwealth's over-all energy management strategy. Specific suggestions on ways to use energy more wisely are presented in parts B and C of this section.

5. Develop and Submit to the Federal Government an Attainable Schedule for Secondary Environmental Standards (Short-Term)

Environmental concerns are of growing importance and must be reflected in governmental actions at all levels. Of particular concern to Pennsylvania, as well as many other states, is the effect of air quality standards on the use of coal as an energy source. The 1970 amendments to the Federal Clean Air Act mandated the Federal Government to develop and adopt nationwide primary air standards (based on health hazards) and secondary air standards (based on public welfare issues). Pennsylvania has developed plans for meeting primary air standards by 1975 as required by Federal law, but it is still working on plans for meeting secondary standards. The application of primary air standards has placed some constraints on the use of coal as a fuel in Pennsylvania, but implementation of the secondary air standards will place further constraints on such use. To help avoid serious fuel shortages during the 70's, while steps are are being taken to develop low-sulfur gas and oil from such coal, the Commonwealth should re-examine the proposed timetable for implementation of secondary air standards in various regions (3) and submit to the Federal Government an attainable schedule for their implementation. Such re-examination must include evaluation of associated risks to the terrestrial and aquatic environment and to human health.

Additional goals regarding environmental standards are discussed in part B-6 of this section. Environmental considerations are discussed in greater detail in Section V of the report.

6. Intensity and Expedite Review of Applications for Energy Facilities (Short-Term)

During the last several decades, the procedures for reviewing and approving the construction and operation of mines, power plants, and supporting facilities have become inordinately lengthy, complicated, and time-consuming at both the state and federal levels.

The procedural complication is almost beyond the belief of those who are not directly involved. It has grown piecemeal as greater attention had to be given to various environmental factors of concern to the state and nation. The same careful attention could be given to these matters, however, by better coordinated and more streamlined procedures. Detailed review and improvement of the processes used by the Commonwealth are urgently needed. The State cannot afford the present procedural delays associated with getting power plants built and operating.

In addition, to help mitigate the problems of energy production and distribution, the present adversary legal system should be reviewed to enable the Commonwealth to produce and distribute energy in a method acceptable to the environment in general, but not limited by individualistic complaints.

7. Promote Collection and Use of Solid Wastes for Use as Fuel (Short-Term)

The Commonwealth should take steps to facilitate the collection, sorting, and burning of combustible waste products to obtain energy from such products at the same time that they are being disposed of. This will require legislative action to enable prospective plants of this type to be assured of obtaining the wastes from the many municipalities usually surrounding a metropolitan center where such a plant might be built. In one Pennsylvania area, for example, a proposal to construct such a plant was dropped because the plant could not be assured of access to the wastes required for its operation.

Incentives should also be provided to encourage manufacturing and processing plants to use their industrial wastes for energy production where feasible. In some instances such wastes might be converted to usable gas or oil or be recycled for use in their output.

8. Provide Adequate Staff for Data Collection and Licensing of Energy Facilities (Short-Term)

Because of the importance of accurate data in making policy decisions, adequate staff must be provided to appropriate state agencies to accumulate, analyse, and assess pertinent data on the availability and needs for various fuels and on on-going energy developments. Furthermore, since decision-making will probably always involve a number of State agencies, all parties involved would be greatly helped by the establishment of a State Expediting Office to assist in planning, scheduling, and coordinating decision-making activities involved in power plant approvals. This Office would provide a focal point both for coordination and for breaking procedural log-jams when they occur. It should be a place to which utilities can turn for help when action is stalled. It is recommended that such an office be established.

B. Energy for the 70's

If appropriate action is taken now, in perhaps 15 years a variety of new processes can provide us with substantial amounts of clean energy from coal and nuclear fuels. Moreover, they should do so at costs competitive with the projected costs of other presently available but dwindling clean-energy fuels. But in the shorter term, there is literally no single course of action open that will fully satisfy both needs for energy and for meeting environmental requirements. We must, therefore, make use of a number of expedients during the next 10 to 15 years, and indeed such expedients are available. However, the situation will improve in 10 to 15 years only if vigorous research and development are accelerated now.

In the interim, early and wide use must be made of the best available technologies to assure health, comfort, and jobs for Pennsylvanians at acceptable environmental and economic costs. Such a Pennsylvania program must promote achievement of the following goals.

1. Wise Use and Conservation of Energy

Since energy comes from valuable material resources, serious attention must be given to using it wisely. A vigorous program of effective energy conservation must be instituted now to help alleviate some of the short-term problems.

The most significant additional energy conservation measures are the installation of improved insulation in both new and old homes; the use of more efficient air conditioners; a shift of intercity freight from trucks to rail, intercity passengers from air to rail and bus, and urban passengers from automobiles to motorized mass transit; and the introduction of more efficient industrial processes and equipment (19). These are discussed below.

a) Provide Public Information and Education (Short-Term)

The Commonwealth should undertake an extensive public information and education program to inform its citizens of the nature of the various energy supply problems facing the Commonwealth and continue to stress the need and methods for conserving energy. It should also promote education with respect to the importance of efficiency in devices utilizing energy.

To promote greater attention to energy conservation, utilities (gas and electric) should expand the technical conservation services which many of them have developed in recent years to help users, particularly large users (both industrial and commercial), to reduce their energy or fuel needs without significantly hurting their production.

b) Modify Building Codes (Medium-Term)

State standards should be set for new buildings, and tax relief or other incentives should be used to encourage the improvement of insulation in existing buildings. Many high temperature industrial furnaces have very low thermal efficiency, because the cost of wasting fuel has been less than the cost of installing heat exchangers and good insulation. This is less so in heavy industry, whose fuel costs are higher, but there is still room for improvement.

c) Keep and Strengthen Rail Transportation (Short-Term)

The need for conservation appears particularly important in the area of transportation where trends in recent years indicate, that with the decline of railroads and the phenomenal growth of automobile and air transportation, we have been getting fewer passenger miles or ton-miles of cargo for each unit of energy being used. For example, reference (2) points out that a fast train used 980 Btu's per passenger mile, whereas an automobile uses over 4000 Btu's, and a 707 jet used over 6000 Btu's. For freight handling, pipelines, trains and barges provide more than 200 ton-miles per gallon of fuel while trucks transport about 50 ton-miles per gallon. The need to develop incentives for the use of more efficient forms of transportation is growing.

In view of the important energy savings which rail transportation can effect both for freight and passengers, greater use of railroads must be made in the years ahead. Therefore, it is imperative that steps be taken not only to prevent our railroads from going out of business but also to strengthen them. Where routes are abandoned, steps should be taken to have the state get control of the rights of way for possible future reuse as railways or energy distribution corridors.

The Commonwealth has various possibilities for controlling energy usage through taxation and tax credits, incentives to become more efficient, peanalties to cut usage; for example, the tax on automotive fuels could be considerably increased if this were deemed useful as a means for rationing available gasoline stocks. Taxing truck fuels could, perhaps, move truck transport onto rail. However, this would have to be done on at least a regional if not a national basis in order to be effective. However, getting considerable freight and goods movement out of trucks onto rail would make available considerable fuel for domestic heating.

d) Plan Appropriate Development of Mass Transportation (Short-Term)

Because of the relatively large amount of energy consumed per passenger-mile by automobile travel, steps should be taken to provide and encourage use of lower-energy consuming mass transportation systems in and around big cities. Specific recommendations regarding mass transportation are being developed by a separate GSAC Energy Panel on Transportation.

e) Examine A Modified Rate Structure for Use of Electricity (Short-Term)

The preset rate structure for electric power should be studied to determine if and how it can be revised to encourage energy conservation. It has been suggested that the rate structure should be inverted so that beyond a certain amount, each unit of energy would cost more rather than less as it does now. This might be done by determining base-level electrical requirements for homes and for various types of businesses and industries and then establishing reasonable rates for usage up to the base levels with increasingly higher rates beyond those levels. The effects of this and other proposals for modified rate structures should be studied.

f) Plan for Conservation of Petroleum (Short-Term)

Petroleum is unique as an energy source in that it is the most widely useful fuel for transporation. In the long term, as an energy source, it should be used primarily for supplying transportation needs. Petroleum also has other important uses for making various types of chemical and chemical products which are not readily attainable from other sources. Hence it should not be used for energy production where coal or other more abundant energy sources are available. Wherever practicable coal should be substituted for oil as an energy source.

2. Effective Use of Current Nuclear and Coal Technologies

Pennsylvania has long been a leader both in the production and use of coal and in the development and use of nuclear power. Effective and enlightened use of coal and nuclear fuels can help the Commonwealth cope with its energy needs for the 70's without undue harm to the environment. The following steps should be taken to achieve this goal.

a) Expedite Construction of Nuclear Power Plants (Short-Term)

The most immediate relief of electrical energy problems in the state can be achieved by facilitating the rapid completion of nuclear power plants which are currently under construction and have proper safeguards against significant hazards to the environment and human health. These plants will significantly augment the present base load capacity of our electrical network without introducing additional environmental problems. It is essential that licensing procedures for these and other power plants be better coordinated and that better means for resolving conflicts with interveners be developed and implemented.

b) Convert to Use of Coal for Producing Power (Short-Term)

In an effort to meet clean-air requirements, a number of utilities and industries in Pennsylvania have switched from burning high-sulfur coal or oil to burning low-sulfur oil, much of which has to be imported into the United States. As the use of such fuel increases, a state of extreme emergency could develop if supplies are cut off or become more difficult to obtain. To mitigate the possible consequences of such a situation, industries and utilities should be encouraged to retain or convert to coal burning plants utilizing coal with the lowest available sulfur content and incorporating the best available and appropriate sulfur-removal technology.

c) Increase Coal Production and Train Coal Mining Manpower (Short-Term)

If increased use of coal is to be achieved as indicated in item 2-b, it will be necessary to greatly increase coal production in the State. Greatest interest will be of course in expanded production of low-sulfur coal, but eventually there will be a need for all usable grades of coal.

Increasing coal production will not be easy. Competition from other lower-cost fuels and increasing coal mining costs have caused many mines, particularly the smaller mines, to close rather than expand. Only the most efficient have been able to survive. To turn the picture around will require new economic incentives and infusion of large amounts of new capital. The State will have to provide important economic motivations to encourage and facilitate increased production of coal. In addition, the Commonwealth will have to cope with a number of other problems, including training of needed manpower; assuring the availability of means for transporting coal; development of improved mining techniques for Pennsylvania seams; resolving public policy questions; and overcoming procedural delays in approving new mining operations and close-out of old operations.

In recent years, there has developed a significant shortage of coal miners. To develop an expanded coal market, this shortage will have to be overcome. The Commonwealth should study the needs for training of individuals for coal mine operations and implement appropriate training and development programs for such individuals.

Despite the challenges involved, coal production must be increased if coal is to be counted on to fill growing fuel shortages.

d) Reduce Sulfur in Bituminous Coal and Use More Anthracite (Short-Term)

Since much of Pennsylvania's bituminous coal is relatively high in sulfur content (2.5 to 3.5%), further attention should be given to use of mechanical and chemical means for removing sulfur from this coal to permit its use within acceptable environmental limits.

Various methods are being studied for removing sulfur in the form of pyrites (iron sulfide) along with a variety of organic sulfur compounds (17). Bureau of Mines experiments have shown, for example, that at least 90% of the pyritic sulfur in coal can be removed by treating the coal at 225°C with aqueous sodium hydride. Subsequent treatment with an acid reduces the ash content to as little as 0.5%. Removal of organic sulfur compounds is more difficult, but research on this effort is continuing.

In other experimental work of the Bureau of Mines, a dry method for removal of pyrite is being studied whereby coal is pulverized and the pyrite is broken free from the coal to be removed by air classification and electrostatic separation. About half of the total pyrite of the coal tested can be removed and discarded in rejects comprising 10 to 15% of the feed.

Laboratory froth-flotation tests have also been conducted with synthetic coal-pyrite mixtures and high-pyrite coal samples to determine if adding various compounds will assist pyrite separation. For each metal salt there appears to be a range of pH values and optimum concentrations for selecting depressing pyrite in coal flotation.

While these processes are only partially developed, encouragement of their appropriate use as well as use of conventional means for beneficiation of coal should be provided to permit more extensive use of Pennsylvania's bituminous coal with less adverse impact.

Pennsylvania anthracites, on the other hand, are relatively low in sulfur (0.5 to 1.5%). Greater use of anthracite coal should be made for industrial heating and steam generation, since little sulfur clean-up would be necessary. There are objections, however; see Section VIII. Nevertheless, for certain circumstances, the possibilities should be explored.

e) Determine Effectiveness of Combustion and Post-Combustion Processes for Sulfur Removal or Dispersal (Short-Term)

It is generally agreed that the best way to eliminate sulfur dioxide from the stack gases of coal-fired furnaces will be to remove sulfur from the coal before it is burned, as will be accomplished by conversion of coal to oil or gas. Until such processes are fully developed, however, considerable attention is being given to combustion and post-combustion methods for removing sulfur compounds as well as to methods for dispersal of sulfur dioxide by the use of tall stacks. Even some of these are developmental, but the work in progress should provide data on the effectiveness and practicability of such methods within the next two to five years. Three such methods are discussed below.

(1) Stack Gas Cleaning

To clean stack gases, they have to be processed through a large chemical system where in the gases are brought into efficient contact with a solid or liquid absorbant to remove the sulfur dioxide present. Several electric utilities have installed or are installing large experimental stack-gas cleaning plants for testing various processes and gaining operating experience with them. The reliability of such systems will be a major factor in their ultimate usefulness. Problems of storing and disposing of the resulting acid sludge must also be solved.

If the experience of present users of full scale stack-gas cleaning units justifies this course of action, the Commonwealth should provide industry with incentives to stimulate installation of stack-gas cleaning equipment, either by permitting recovery of costs through price increases, or by the avenue of tax relief. Low interest loans are available through the State's Revenue Bond and Mortgage Program.

(2) Use of Lime or Dolomite with Coal

Coinjection of lime or dolomite with coal has been tested in the U. K. as a means of reducing sulfur emissions in power stations of the currently used type. This expedient does not reduce emissions by more than about 20%

but this would be sufficient with some marginal coals. However, larger precipitators may well be needed to remove the particulates from the stack gas. Use of this expedient should be explored.

(3) Tall Stacks

Tall stacks (500 to 1000 feet in height) are being used by some utilities and are being considered by others to release effluents at elevations where dispersal and dilution of pollutants (of which sulfur dioxide is only one) can be more readily effected than is done by more conventional stacks. Tall stacks are of interest because present air pollution regulations have usually been interpreted as being concerned with the direct local pollution from a particular source. Little attention has been given so far to contributions from other sources and the effects of all sources on the global pollutant background. The present global background of pollutant concentrations is small compared to the concentrations near sources, but the build-up of these quantities must be watched carefully, particularly those which could influence climate, such as CO_2 and small particulates (18).

The local effectiveness of tall stacks is influenced by a number of meteorological factors which vary from time to time including effects of turbulence, temperature, humidity, and solar radiation. Thus the intensity and duration of ground-level concentrations of pollutants from tall-stack plumes can vary greatly from time to time.

Reference (18) points out that ultimately, material emitted into the atmosphere from power plant sources becomes mixed through the lower atmosphere, the troposphere, if it is not removed by some natural process. Typically the residence time for such materials in the lower atmosphere is measured in weeks.

There is a need to know more about the eventual fate of pollutants in the atmosphere and their influences on the earth's environment. But it appears that for the present tall stacks can provide an interim method for mitigating local pollution problems. If high level dispersion techniques can be used to keep ground level concentrations within EPA standards, many grades of Pennsylvania coals can be used by utility and large industrial plants.

f) Use Available Technologies to Meet Primary Air Standards (Short-Term)

The use of various expedients to supply energy during the 70's should not and, in large part, need not impede the progress being made in implementing the primary air quality standards in Pennsylvania. By effective use of available technologies, such as described under items d and e above, these standards generally can and should be met.

In those situations where critical shortages exist and more time is needed to obtain and install anti-pollution equipment, temporary variances should be allowed under specified conditions and with appropriate monitoring of effluents. Wherever feasible in such instances, provisions should be made to use clean fuels during periods of atmospheric inversion when dispersal of pollutants is minimal.

With regard to implementation of new standards, the following two additional points should be considered.

(1) In general, environmental control standards should be applied on a time scale consistent with the ability of technological developments to cope with them. In the interim, pollutants should be controlled by the best practicable and efficient method unless it can be shown that less strangent methods will provide controls that will not damage the structure and functioning of the terrestrial and aquatic ecosystems and will not be damaging to human health. Large step changes in environmental standards which cannot be met realistically cause severe economic and social upheavals. For example, the sulfur emission standards established by EPA which apply to power plants are based on the premise, which has not been substantiated by the market place, that commercial processes for removing SO_2 from stack gases are available. Lacking such devices, however, many electric utilities have had to convert to burning more difficult-to-get-low-sulfur crude oil or low-sulfur coal. Such action adds acute but unnecessary perturbations to the overall energy-environment problem.

(2) Standards need not be applied uniformly at all locations at the same time to be effective. While eventually all polluters must be required to comply with regulations, action is most effective when it is applied first where it is most needed. In some instances where environmental and health data indicate that less stringent standards would not result in harm (such as in lightly populated areas), the standards for these areas may be less restrictive, but they should be accompanied by requirements for frequent if not continuous monitoring.

3. Expansion of Pennsylvania's Energy Supply and Distribution Systems

The growing needs for energy will require not only sustaining but also expanding current fuel supplies. Continuing attention must be given to assuring uninterrupted availability of sufficient fuels if major crises are to be avoided. A number of steps can be taken now to help the situation in the years ahead. Some of these must be taken on a national basis, but there are actions which should be taken by the Commonwealth. These are discussed below.

a) Develop Power plant and Transmission Siting Criteria (Medium-Term)

The availability of suitable sites for electric generating plants, particularly nuclear plants, is constrained by a number of factors including geologic and meterologic requirements and the supply of water for cooling purposes. The Commonwealth should plan now to help utilities in locating power plant sites, obtaining appropriate state and federal approval of such sites well in advance of their need, reserving or procuring them for future sale or lease along with corridors for transmission lines, and integrating power plant sites and recreational facilities to form power parks. A special GSAC Panel on this item has been formed and more detailed recommendations on this subject will be submitted when the Panel has completed its work.

The need to site power plants at specific locations will also require the development of energy distribution corridors either under the auspices of the Commonwealth or by acquisition by the public utilities. The conservation of land requirements would indicate the development of an overall plan in the Commonwealth for energy corridors to transfer energy in the form of liquid, gaseous, or electrical. Presently available locations, such as interstate highways and turnpikes which have already consumed the land, might be considered for this purpose; existing and abandoned railroad rights of way are another possibility. Criteria for power plant siting must be accompanied by criteria and means for siting distribution systems to transmit energy from the power plant location to the urban centers where utilization will occur.

b) Create Climate for Effective Financing of Facilities for Supplying Energy

Efforts should be made to help utilities in financing of energy producing facilities and power stations. This might be done by tax incentives as well as allowances for reasonable return on investments. Incentives such as tax-free bonds might also be used to help finance antipollution devices.

To illustrate the magnitude of the problem, a representative of a Pennsylvania utility recently stated that "the capital requirements of an electric utility are the highest in the nation." He further stated, "Because of the regulation on the amount of return allowable, most electric utilities can only internally generate approximately 20% of their needed capital. Eighty percent of the needed capital must come from the money market." He also reported that "in the next five years, the Pennsylvania utilities alone will require approximately 5 billion dollars in capital to enable us to construct the necessary generation and distribution facilities. When one realizes that at least 4 billion of this must come from stocks and bonds, it becomes an awesome picture. The only way that companies can attract this kind of capital is to have a good financial position and a good earning position."

If utilities must pay 9 to 10% interest on borrowed capital their earnings on capital cannot be limited to 7%.

The Commonwealth of Pennsylvania could also help itself by promoting the construction and development of additional liquid and gaseous fuel storage facilities so that these could be filled off peak and then resold. Perhaps, the state itself could develop this sort of cushion on a no cost or slightly profitable basis to itself as a service to industrial, commercial, and residential users of these fuels.

c) Use Wood and Urban, Agricultural, and Industrial Wastes as Energy Sources Where Practicable (Medium-Term)

Although wood is no longer considered to be a major source of energy, its possible use as a power plant fuel should be re-examined. It has been estimated that 900 square miles of forest could supply a 1000 MWe power plant on a continuous basis. This assumes a 75% load factor for the power plant and a 1/2% efficienty of utilization of solar energy delivered at an average rate of 1500 Btu per square foot per day (16). With all of the forest in Pennsylvania, this might be a significant interim source of energy if power plants can be designed and built to economically use this resource within acceptable environmental standards.

Agricultural products are also potential sources of energy and should be studied as possible supplements to fossil fuels. Agricultural wastes too can be used to provide fuel for a number of uses. Manure, for example, is used, in various parts of the world, as a source of methane gas. Exploration of the potentialities of such approaches should be made, particularly for supplementing energy needs in rural areas.

As indicated in part A-7 of this section the use of urban and industrial wastes for producing power should be encouraged. The problems of using such wastes without large adverse enrironmental effects should be studied. Some of these wastes might possibly be converted to gas or oil for clean burning.

d) Support Deep-Water Ports for Oil Import (Medium-Term)

The United States will have to build a number of deep-water ports or anchorages to import economically enough petroleum to meet its growing demands. To handle the large volume of foreign oil which this country will need in the years ahead, extensive use will be made of large tankers of 250,000 to 500,000 tons. Deep-water ports or anchorages with pipe line connections to shore will be needed for such tankers in the East, otherwise eastern states such as Pennsylvania may find themselves paying higher prices for oil than other states, such as the Gulf Coast States, where deep-water ports would undoubtedly be built. We would then have to rely more strongly on heavily-burdened pipelines or other means of more costly transportation. Studies should be started soon to determine the economic and environmental consequences of constructing or not constructing deep-water ports or anchorages in the Middle Atlantic States. If such studies confirm the need for such ports for Pennsylvania, as GSAC feels they will, action should be taken to get them built.

C. Clean Energy for the 80'S: Leadership in New Technology

Aggressive Pennsylvania participation in vigorous development of clean energy options for the 80's must begin now and persist for a number of years. Such a Pennsylvania program should include activities in four important areas which are discussed below.

1. Efficient Energy Use

Usage of energy generally implies usage of irreplaceable natural resources. Hence continuing long-range attention must be given to means for energy conservation if adequate energy resources are to be available to future generations. Furthermore, certain fuels are better suited to fulfilling specific energy needs or other needs than are their counterparts. Petroleum, for example, is the primary source of fuel for most forms of transportation. Both coal and petroleum are valuable sources of chemicals. Thus energy conservation programs must be geared not only to saving fuels per se alone, but also to saving them for particular uses. The following actions should be taken to achieve this goal.

a) Develop New Means for Energy Conservation and Efficient Use (Medium-Term)

Studies are needed to provide new enlightened and effective means for conserving energy. In addition to the items previously listed under B-1 above, the following items should be among those considered.

(1) A sustained and effective long-range education campaign not only on the value of conservation, but also on the means and the incentives for conserving energy. This educational process should be regarded as a continuing responsibility by government, universities, industry, churches, service clubs, etc., with the best material made available to them.

(2) Incentives to provide and use more efficient industrial, commercial, and residential equipment, particularly more efficient home air conditioners, and to maintain equipment at peak efficiency.

(3) Strong research programs on improving all technologies relevant to increasing efficiencies of existing energy producing, storing or transmitting systems.

(4) Tax incentives to encourage lower energy usage per unit of production by industry.

(5) Encouragement to manufacture products which have longer lives to conserve on the energy needed to make more frequent replacement products.

(6) Economic incentives to encourage greater use of mass transportation systems.

Long-range benefits will include not only alleviation of potential shortages, but time for development of alternative forms of long-term energy production such as energy from fusion which is projected for beyond the year 2000.

b) Develop Further Means to Convert Wastes to Fuel or Direct Heat (Medium-Term)

The use of urban, agricultural, and industrial wastes to provide energy for the 70's are discussed in parts A-7 and B-3-c of this section, but further development of means for using such wastes efficiently and with reduced harm to the environment and human health will be necessary if the full potential of using wastes for energy is to be achieved. Particular attention must be given to collecting and sorting of wastes as well as to the optimum means for burning them. Enabling legislation and incentives will be needed to promote collection and use of such wastes. Support of research to solve the technological problems associated with preparing and burning wastes efficiently will also be needed.

c) Develop and Encourage Mass Transit and Rail Freight Facilities (Medium-Term)

In part B-1-c and d of this section, emphasis is placed on keeping and strengthening railroads and providing expanded mass transit facilities. However, more long-range attention to these means of transportation is also needed. It is clear that facilities in these areas will have to be modernized and expanded to encourage their greater use. This will require considerable infusion of new capital and re-examination of taxing procedures to facilitate achievement of this goal. We must take advantage of new technologies and approaches developed in our own country as well as other countries to provide fast and efficient rail service. More extensive use of electrification of railroads (particularly on main lines) should be considered to cope with forthcoming shortages of oil as an energy source; through electrification, nuclear power plants and efficient coal-fired plants can be used to provide clean energy for railroads without the need for petroleum products which should be retained for air transportation and other uses.

Unless adequate rail facilities and other forms of mass transit (on a scale far greater than we have now) are planned for now and built within the next decade, we will face a catastrophic breakdown in our ability to feed, clothe, and house our people during the 80's when gasoline for automobiles and other road vehicles becomes far more scarce than it is now.

2. Modern Coal and Nuclear Technology

The needs for advance coal and nuclear technologies to provide clean fuels and for new public policies to govern their use present Pennsylvania with an opportunity unparelled in this century. Pennsylvania is particularly well qualified to accept the challenge and should do so for the continued future well-being of its citizens. Specific areas for action are discussed below.

a) Intensify Mapping of Pennsylvania's Reserves (Medium-Term)

To facilitate future planning, detailed geologic and mapping of Pennsylvania's coal, oil and gas reserves will be needed.

Data on coal are needed, not only to identify the seams which can be most readily mined, but also to plan and encourage the development of effective means and equipment to recover coal in seams of various thicknesses and pitch angles which are more difficult to mine. Furthermore, such data are needed to inventory and evaluate sites in Pennsylvania capable of supporting plants for conversion of coal to oil or gas; such plants will require 5 to 10 million tons of coal per year for a plant life of 20 years or more (a total requirement of 100 to 200 million tons or more).

Data on oil and gas reserves are needed to inventory and evaluate promising fields for secondary or tertiary recovery as discussed in part C-2-a of this section.

b) Develop Improved Coal Mining Techniques (Medium-Term)

Because of the importance of coal to Pennsylvania, the Commonwealth should maintain an active program of research aimed at expanded future use of its coal as an energy source in the state. This effort should include the development of improved technologies for the mining, cleaning, transporting, and burning of coal, and for subsequent disposal of wastes.

Of particular importance is the need for research on the development of safer and more economical systems of underground recovery of coal--especially for seams less than thirty-six inches thick and/or pitched seams--as well as for methods of surface mining that are compatible with society's wish to avoid strip mine damage. The most economic seams for mining are thirty-six inches or thicker. Pennsylvania has many seams that are thinner than this, but the techniques for coping with these thinner seams are not readily available. Also, many of Pennsylvania's coal seams are pitched at severe angles, and better techniques for coping with pitched seams are needed.

c) Support Conversion of Coal to Oil or Gas (Medium-Term)

Because of the importance of converting coal to oil or gas, the Commonwealth should encourage and support acceleration of research and development work in this area. It should also encourage the dedication of promising coal fields for coal conversion pruposes and provide incentives and financial help for getting coal conversion plants started.

To this end, the Commonwealth should catalyze the construction of a 100 ton/day coal liquifaction pilot plant in Pennsylvania, using funds from both the private and public sectors, to convert Pennsylvania coal into a low-sulfur, pumpable fuel oil.

In addition, the Commonwealth should offer state assistance and financial incentives to stimulate industrial construction of a low-Btu gasification plant linked to a combined cycle power station.

d) Encourage Development of Nuclear Technology with Emphasis on Safety and Disposal of Heat and Wastes (Medium-Term)

Nuclear power will undoubtedly play an important role in the generation of electricity in Pennsylvania. Its ability to provide clean energy has been well established provided appropriate emphasis is placed on safety and disposal of wastes. The Commonwealth should promote and insist on the highest standards of safe design and operation of such plants with attention to both preventing possible accidents (even low-probability accidents) and limiting the possible consequences of accidents. Although the responsibility for governmental activity in this area is in the hands of the U. S. Atomic Energy Commission (USAEC), the Commonwealth should expand its staff in this area to work with the AEC in the review and surveillance of such plants.

As the number of nuclear power plants increase in Pennsylvania, the problems of disposing of nuclear wastes will become increasingly important. The Commonwealth, in cooperation with the USAEC and local industries and utilities, should be planning its strategy for transporting and disposing of nuclear wastes. The disposal of such wastes involve extensive reprocessing plants to reclaim the valuable unused fuels and to prepare the scrap material for burial at an approved site. Pennsylvania's geologic structure is not particularly well suited to such burial unless very deep storage (in cavities developed by underground explosives a mile or more below sea level) turns out to be feasible. If Pennsylvania does not have its own reprocessing and burial facilities, it will have to assure itself of the development of cooperative arrangements with states having such facilities and with states through which nuclear wastes must be transported.

The Commonwealth should also give consideration to the need for facilities to provide enriched uranium for nuclear power plants. In the past, uranium enrichment has been carried on primarily by the federal government.

This situation is on the verge of changing, however, with a number of private companies preparing to possibly undertake such activities. There is potential for developing a uranium enrichment facility in Pennsylvania to help its nuclear industry. The Commonwealth should evaluate the merits and problems of encouraging the location of such a plant in Pennsylvania. The smallest projected plant might have a capital investment of one billion dollars, an operating budget of 80 million dollars, and employ about 1,000 people.

In the future, it is expected that breeder nuclear reactors will become an important source of energy, probably during the latter part of the twentieth century. These can be divided into three categories--sodium-cooled, gas-cooled, and steam-cooled. Work on development of the sodium-cooled breeder has been given top priority, by the USAEC, on the basis of potential economy and technological experience. Some of this development work is going on in Pennsylvania industries. In anticipation of use of such breeders, the Commonwealth should consider the characteristics of these plants in its siting studies. In addition, the Commonwealth should encourage specific studies of materials problems in breeder reactors, since its industries and universities have extensive expertise in the field of materials development.

e) Stimulate Growth of Energy Equipment Industries (Medium-Term)

Much of Pennsylvania's industry is involved in manufacturing energy generating and transmission equipment as well as equipment for use of energy in the home, business, and plants of all kinds. The needs for more energy and for more efficient use of energy in the United States and the rest of the world provide the state with opportunities for growth in these industries. Such growth will play an important role in providing jobs which might be lost as living patterns of people change when specific fuel shortages materialize. The Commonwealth should encourage the growth of such industries, and at the same time help other industries adapt to changing conditions.

3. A Domestic Petroleum Supply

Today both the state and the nation are relying increasingly on foreign oil as a source of clean energy. With appropriate use of its coal reserves and nuclear fuels, the United States, and in turn Pennsylvania, can reduce its dependence on foreign petroleum for much of its energy. But further steps should be taken insofar as possible to reduce our dependence upon foreign sources for petroleum per se. To this end the following two actions are recommended.

a) Develop Means to Get Oil and Gas from Old Wells (Medium-Term)

The potential for increasing production of oil in Pennsylvania lies primarily in the potential for secondary or tertiary recovery from oil fields which have already been tapped. Between 50 and 65 percent of all known reserves remain in the ground after pumping by normal methods because there is either insufficient pressure to extract additional oil or the remaining oil adheres to grains of sand or are trapped in hard soils or rock formations.

Secondary recovery by hydro-fracturing solid formations and using compressed air or water under pressure are coming into increased use in Pennsylvania because of increasing value of Pennsylvania crude petroleum with the high parafin content. It yields about 10 to 15 percent additional product from the initial reserve.

Tertiary recovery methods are in their infancy. The method involves dissolving the residual crude with solvents, then moving the dissolved material to removal wells by means of a pressured slug of highly viscous fluid. The process involves tailoring to each crude oil pool. Recovery is very high resulting in almost complete removal of the original reserve.

Tertiary recovery needs a systematic cost benefit analysis, and support of research in bottleneck areas. A small investment will yield significant results.

b) Consider Drilling for Oil in Lake Erie (Medium-Term)

There is a significant amount of oil underlying Lake Erie. Off-shore drilling in Lake Erie has been prohibited within the boundaries of Pennsylvania. This matter should be reconsidered. The Canadians are drilling wells in the portion of Lake Erie lying within their boundaries.

4. Protection of Environment and Health

To provide a more effective basis for balancing the needs to protect human health and the environment with the needs for energy, the Commonwealth should encourage federal and private research in a number of areas as indicated below. Use of Pennsylvania institutions for carrying out such research should be encouraged where appropriate. Research in areas of specific concern to Pennsylvania should be supported by the Commonwealth if other funding is not available. The following subjects should be included in a research program on energy matters affecting human health and the environment.

a) The fate of pollutants from combustion processes.

b) The effect of pollutants on human health, materials, and urban and rural environments. This work should include effects of low levels of pollution as well as high levels.

c) Means for minimizing health hazards to miners.

d) New technologies for coal mining.

e) Alternative sources for energy production and usage which better protect human health and the environment.

D. Development of Other Advanced Energy Systems

Looking beyond the 80's, the Commonwealth should encourage development of clean energy systems which will be needed for the future. Earlier reference has been made to some of these such as the breeder reactor. Other systems include the following.

1. Fusion (Long-Term)

Fusion is potentially one of the most environmentally attractive energy sources conceived by man. Its primary fuel would be the stable (nonradioactive) doubly heavy isotope of hydrogen, deuterium, which is abundant in sea water. One gallon of sea water has the fusion energy equivalent to that of 300 gallons of gasoline. The National Academy of Sciences has calculated that the fusion energy available from a cubic mile of sea water is equivalent to that from combustion of 5,700 billion barrels of crude oil or two and half times the world's entire oil reserve (4).

Despite research and development work in progress, fusion power plants will probably not come into being until after the year 2000 because of the problems associated with confining the extremely high temperature plasmas required for such reactors. Since work on fusion is being done under federal funding, there is little that the Commonwealth should do at the present time in this field except to follow progress and encourage Pennsylvania industries and universities to participate in related research and development work.

2. Solar Energy (Medium-Term)

Serious attempts to use solar energy developed nearly a century ago, and practical applications have been made to residential water heating in various parts of the world (5). Because of the later availability of cheap power these applications did not become widespread. Today the need for clean energy dictates that the potential for economic and practical use of solar energy be exploited. The Commonwealth should encourage and support research and development work dealing with the problems of applying solar energy in Pennsylvania.

3. Geothermal Power (Long-Term)

In 1970 Congress passed the Geothermal Steam Act to stimulate development of geothermal resources. The use of geothermal sources is receiving significant attention in countries such as New Zealand, Italy, and the Soviet Union, but in the U. S. only Pacific Gas and Electric has been using geothermal steam from the Geysers, north of San Francisco, to produce up to 184 MW of electricity. In Pennsylvania we do not have geothermal steam available, but by deep-drilling (several miles) it is theoretically feasible to extract heat from rock formations, (which would have to be fragmented) to provide steam for generating electricity. The potential is real, but the problems are many; they include not only those of deep drilling, extracting heat, and avoiding subsidence, but also the problems of handling corrosive hot water and the need to use turbines operating at relatively low temporatures with only modest efficiencies (6). Nevertheless, the Commonwealth should study the economics and practicality of using geothermal energy as an energy source in Pennsylvania.

4. Energy Storage Systems

The energy problem is complicated by the fact that energy cannot be readily stored. The chief method for storing large amounts of energy is that of using energy, when readily available, to pump water from a low-lying level to a higher-level reservoir from which hydroelectric power can be extracted when it is needed. When our energy demands grow to the levels expected in the year 2000, more attention may have to be given to storing available energy for peak period usage. The possible needs for storage reservoirs should be considered in developing appropriate power plant sites. In addition, the Commonwealth should support the study of other practical means for energy storage in the state.

E. Developing New Means for Energy Conservation (Long-Term)

Usage of energy generally implies usage of irreplaceable natural resources. Hence continuing long-range attention must be given to means for energy conservation if adequate energy resources are to be available to future generations. Furthermore, certain fuels are better suited to fulfilling specific energy needs or other needs than are their counterparts. Petroleum, for example, is the primary source of fuel for most forms of transportation. Both coal and petroleum are valuable sources of chemicals. Thus energy conservation programs must be geared not only to saving fuels per se alone, but also to saving them for particular uses.

Studies are needed to provide new enlightened and effective means for conserving energy. In addition to the items previously listed under C above, the following items shoul be among those considered.

1. A sustained and effective long-range education campaign not only on the value of conservation, but how it can be done, and the incentives for conserving energy. This educational process should be regarded as a continuing responsibility by government, universities, industries, churches, service clubs, etc., with the best material made available to them.

2. Incentives to provide and use more efficient industrial, commercial, and residential equipment, particularly more efficient home air conditioners, and to maintain equipment at peak efficiency.

3. Strong research programs on improving all technologies relevant to increasing efficiencies of existing energy producing, storing or transmitting systems.

4. Tax incentives to encourage lower energy usage per unit of production by industry.

5. Encouragement to manufacture products which have longer lives to conserve on the energy needed to make more frequent replacement products.

6. Economic incentives to encourage greater use of mass transportation systems.

Long-range benefits will include not only alleviation of potential shortages, but time for development of alternative forms of long-twrm energy production such as energy from fusion which is projected from beyond the year 2000.

IV. Energy Needs and Sources

A. For the United States

To better understand the energy supply and demand situation in the Commonwealth of Pennsylvania it is necessary to have a picture of the situation which the United States faces as a whole. This summary is based largely on data and observations by Dr. John J. McKetta, Chairman of the Advisory Committee on Energy to the U. S. Secretary of the Interior, as reported in references (7) (8) and (9).

1. The usage of energy in the United States has exceeded production in the period 1956 through 1972. See Fig. 1 (8). The deficiency has been made up by imports. In 1972 about 15% of the total energy used in the U. S. was imported.

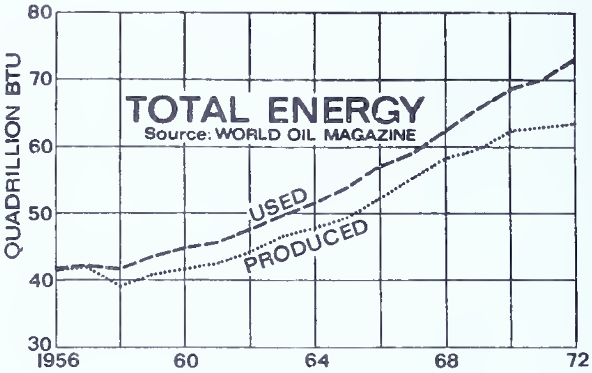


Figure 1

2. In the United States, since early 1967, less gas has been discovered than has been produced or used as shown in Fig. 2 (8). This situation is not likely to change in the next several decades. In 1972 about 9% of the total gas energy used in the U. S. was imported.

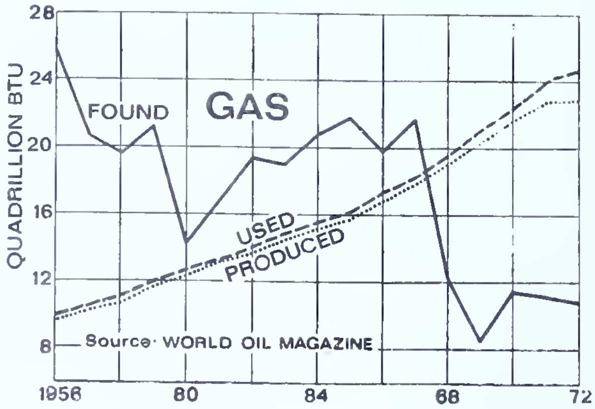


Figure 2

3. As in the case of gas, less oil is being found in the U. S. each year than is produced or used, as shown in Fig. 3 (8). In 1972 about 30% of liquid hydrocarbon used in the U. S. was imported. This increased to over 35% in 1973.

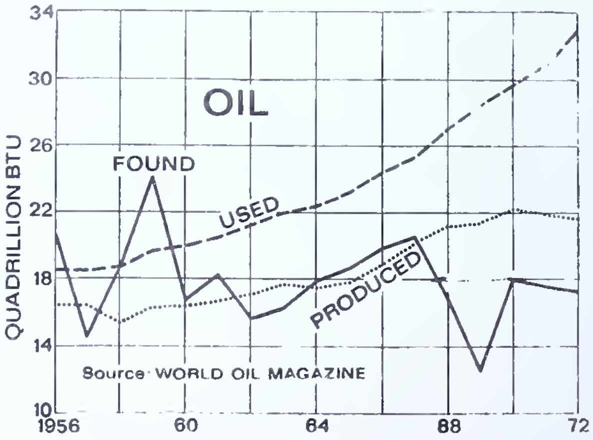


Figure 3

4. The U. S. has consistently produced more coal than it uses, as shown in Fig. 4 (8). Coal has been exported to Germany and Japan since 1946 as part of reparations agreements. The effect of the Mine Safety Act and EPA regulations on the production and usage of coal in 1971 is noticeable. About 22% of the coal mines were closed. Nevertheless growing energy demands led to upturn in coal usage and production in 1972.

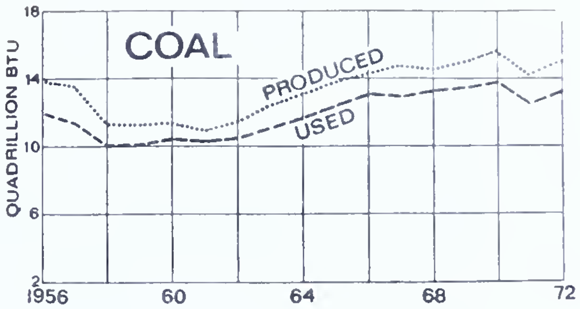
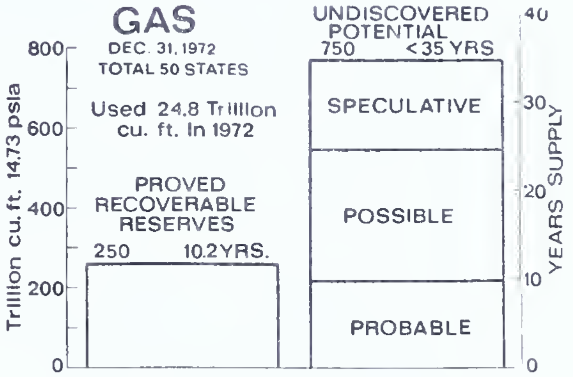


Figure 4

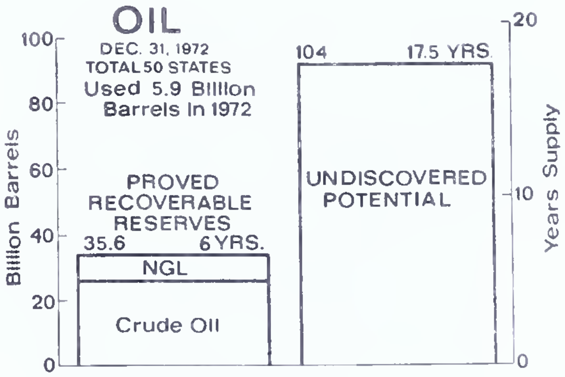
5. Proved recoverable reserves of natural gas amounted to 291 trillion cubic feet in 1970 (7). In recent years, the average volume of new gas reserves found amounted to only half the volume produced. Figure 5 (8) shows these reserves to be 250 trillion cubic feet as of Dec. 31, 1972. At the usage rate in 1972, these reserves would last about 10 years. The undiscovered potential might be as high as 750 trillion cubic feet. Even this amount would last only 30 to 35 years at the 1972 usage rate.



Source: WORLD OIL MAGAZINE

Figure 5

6. Proved reserves of crude oil and natural gas liquids, exclusive of those on the Alaskan North Slope (not available until delivery facilities are approved and completed), have declined from 39 billion barrels in 1957 to 37 billion barrels at the beginning of 1971. North Slope reserves are estimated at about 10 billion barrels (7). Fig. 6 (8) shows available proved reserves to be 35.6 billion barrels as of Dec. 31, 1972.



Source: WORLD OIL MAGAZINE

Figure 6

This amount would last about 6 years at the 1972 usage rate. The undiscovered potential in the lower 48 states is estimated to be 104 billion barrels as shown in Fig. 6. This would last about 17.5 years at the 1972 usage rate. Large quantities of new oil are also expected in Alaska if developments are allowed (7).

Reserve estimates are based on recovery of 31% of the 425 billion barrels of discovered oil under present cost and price conditions. Recovery from many fields could be increased if prices improved enough to warrant additional investment and operating costs needed for greater recovery, technically feasible in years ahead (7).

7. The potential resource base for coal is estimated to be nearly 800 billion tons of which nearly 200 billion tons are available with current mining technology and economic conditions (10). See Fig. 7. At the 1970 rate of consumption of 525 million tons per year, 800 billion tons would last about 1500 years.

Despite the abundance of coal, a shortage is developing because the competition from other lower-cost fuels and increased coal mining costs have enabled only the most efficient operations to survive. Use of high sulfur coals is also now being restricted for environmental reasons.

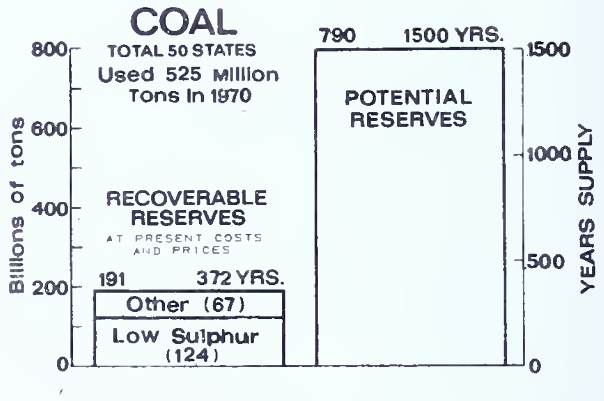


Figure 7

8. The growing gap between the total demand and the total supply for all types of energy, as estimated in January 1970, based on 1969 data, is shown by the top two lines of Fig. 8 (8). To fill this gap the United States will have to import increasing amounts of its total energy needs reaching about 35% by the year 2000. These data assume a minimum U. S. population of 271 million by the year 2000, reasonable application of environmental standards, and no new major energy usage such as general weather control or defogging of cities.

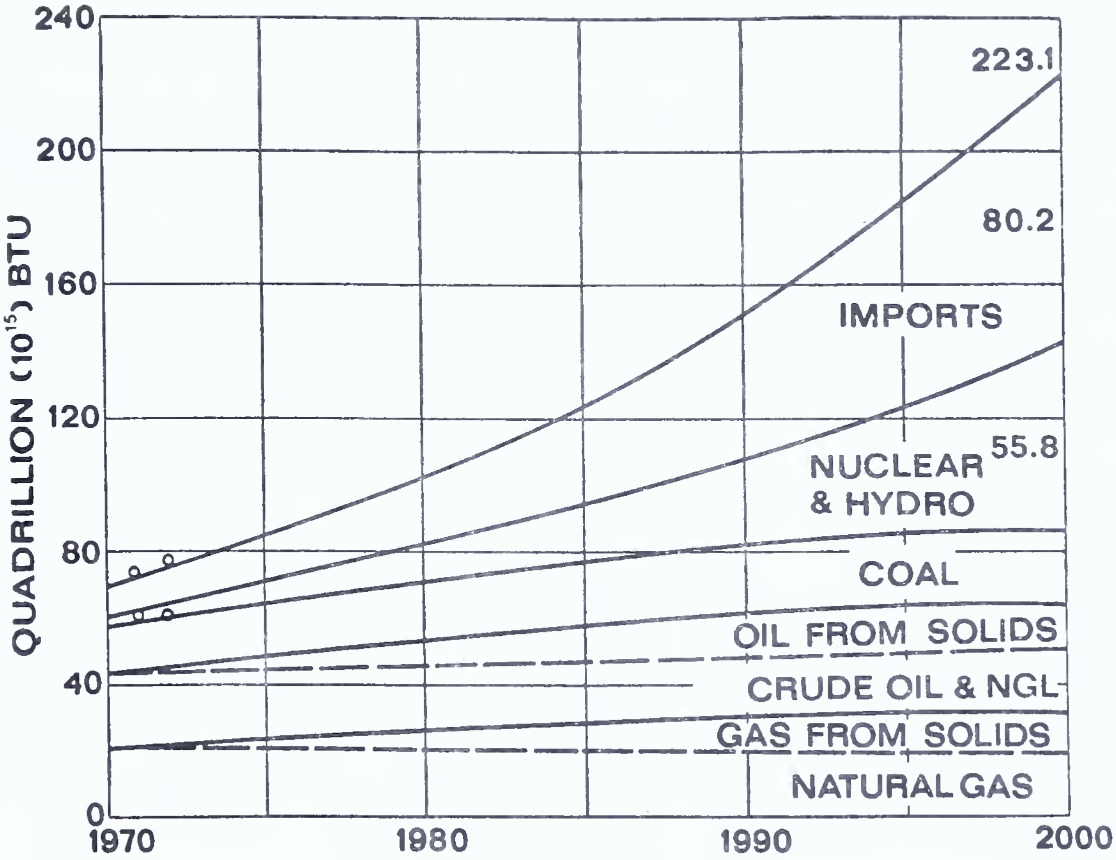


Figure 8

9. Revised estimates based on experiences in 1970, 1971 and 1972, indicate that the U. S. energy situation is more crucial than previously anticipated. Figure 9 (8) shows (for the period 1970 to 1985) a comparison of demand and supply curves estimated in 1970 (solid lines) with the demand and supply curves estimated in 1973 (dashed lines). The demand curve has risen and the supply curve has dropped. Unless severe rationing takes place, the amount of energy imported will approach 50% of the total energy demand. J. J. McKetta (8) points out that this would be equivalent to 12.1 billion barrels of oil each year and, assuming the oil were available for import, would involve an annual total cost of 72 billion dollars. He adds that it would take a pipe 38 feet in diameter following continuously at the optimum rate of flow to transport 12.1 billion barrels of oil per year. In terms of tankers, he estimates, "This means we would need over 1,000 tankers of one million barrels net capacity (we have none yet of this size) continuously on the high seas to make this delivery."

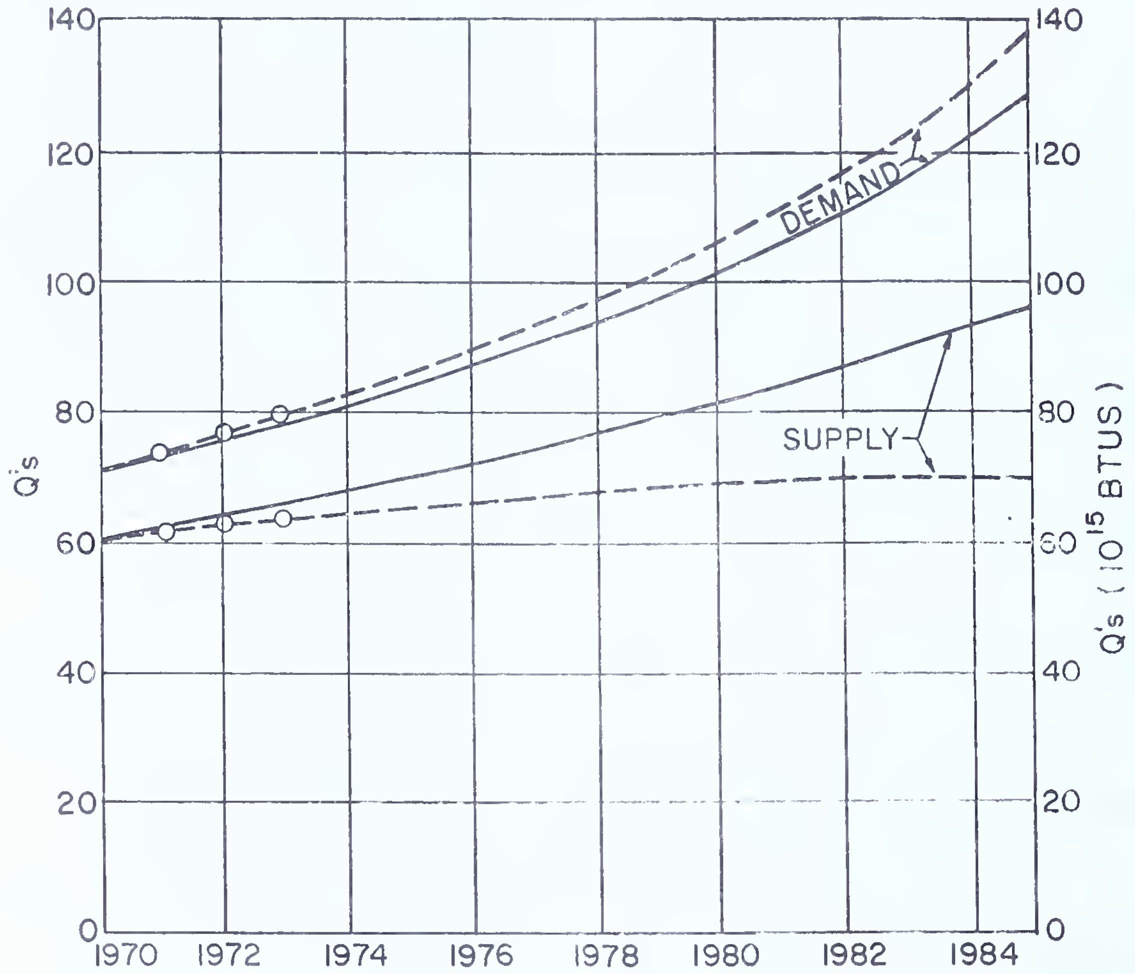


Figure 9

10. In estimating future energy resources, there is a tendency to be overly optimistic about the time frame in which new energy sources can be developed. Table I (8) shows the breakdown of energy from various sources as estimated for 1985 in 1970 and 1973. The 1970 projection overestimated the rate of construction of nuclear power plants and the conversion of solid fuels into oil and gas.

TABLE I - ENERGY SOURCES, 1985

U. S. Sources in 1985	Quadrillion (10^{15}) Btu Predicted in 1970	Quadrillion (10^{15}) Btu Predicted in 1973
Oil & Liquid	18.7	18.2
Gas	16.6	15.5
Coal	20.5	18.0
Nuclear & Hydro.	18.5	10.9*
Oil from Solids	8.4	1.7
Gas from Solids	12.3	2.0
Geothermal	0.15	0.09
Solar	0.10	0.01
Fusion	0.00	0.00
Hydrogen	0.005	0.005
Winds, Tides, etc.	0.0005	0.0005
	95.25	66.405

*If all planned nuclear plants are actually built.

B. For the Commonwealth of Pennsylvania

The requirements for energy vary substantially among the various regions of the United States. Table II (10) shows the relative percentages for energy use and population for the various regions shown in Figure 10.

TABLE II

POPULATION AND ENERGY USE BY REGIONS OF U.S. - 1970

Region	Population	Energy Use	Per Capita Use
	-Percent of Total U.S.-		Millions of Btu Per Year
East Coast	39	31	192
North Central	33	34	250
Gulf Coast	12	20	414
Rocky Mountain	2	3	283
West Coast**	14	12	209
Total U.S.	100	100	1348

**Includes Alaska & Hawaii

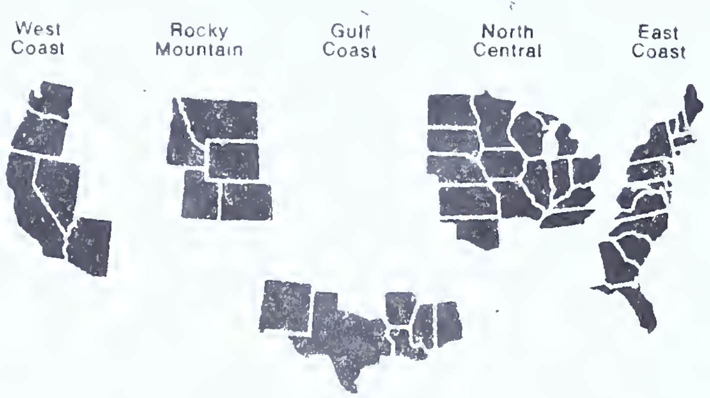


Figure 10

Reference (10) states: "Although the East Coast has the largest share of the nation's population, it does not account for the largest proportion of over-all energy use. In fact, it has the smallest per capita consumption of the five regions. But the Gulf Coast, with little more than an eighth of the nation's population, nevertheless accounts for a fifth of the total energy use and has by far the highest per capita rate of consumption."

Pennsylvania's energy needs on a per capita basis do not conform to the average for the East Coast region. As a matter of fact, its per capita energy consumption is above the average for the nation. Its population is 5.7% of the U. S. population, but it currently consumes approximately 6.8% of the energy. However, as shown on Page Pennsylvania is an efficient user of energy.

The 1970 patterns for energy usage in Pennsylvania, as determined by the Bureau of Statistics, Research and Planning, Pennsylvania Department of Commerce are given in Table III.

TABLE III - ENERGY USAGE IN PENNSYLVANIA - 1970

(In Trillions (10^{12}) of Btu's)

Energy Source		Energy Use	
Coal	1775	Direct Industrial Use	1325
Petroleum	2064	Electric Utility Use	1369
Natural Gas	765	Transportation	767
Hydroelectric	13	Residential Use	756
Nuclear	5	Commercial Use	405
Total	4622	Total	4622

Based on the 1970 energy use patterns for Pennsylvania and the estimated trends in supply of primary mineral fuel and secondary energy sources, the Office of State Planning and Development prepared estimates of Pennsylvania's total energy requirements by five-year steps for the period 1980 to 2000 (11). These are shown in Table IV.

TABLE IV - PENNSYLVANIA ENERGY CONSUMPTION FORECASTS

TOTAL ENERGY, ALL CATEGORIES

Year

1. 1980 - 6,603 x 10^{12} BTU
2. 1985 - 7,975 x 10^{12} BTU
3. 1990 - 9,560 x 10^{12} BTU
4. 1995 - 11,210 x 10^{12} BTU
5. 2000 - 13,157 x 10^{12} BTU

NOTE: These constitute the high estimates of Pennsylvania consumption in keeping with optimistic investment estimates.

The figures in Table IV are based on U. S. Department of Interior forecasts ("United States Energy Through the Year 2000") which were used to establish the high rates of consumption. Importance was attached to the fact that most responsible authors believe we are relatively "locked-in" to our current consumption patterns at least until 1985 due to the lengthening of the time currently required in planning, preparing, and constructing alternative processes and facilities that would be required to appreciably alter current patterns (11). In addition to the estimates of gross energy needs, the Pennsylvania Department of Commerce has recently compiled the data for 1973 with regard to the consumption of fuel by type and end use (22). From these data, a projection by type and end use has been made for the year 1983. These data are given in Tables V, VI, VII and VIII.

TABLE V

All Fuels (1973)
Consumption by Fuel Source

V. a.	%	BTU's (10^{12})
Petroleum	44	2,288
Coal	39	2,028
Natural Gas	16	832
Wood, Hydro, Nuclear	1	52
	100%	5,200

This total energy consumption of 5,200 (10^{12}) BTU was used in the following manner:

Consumption By End Use

V. b.	%	BTU's (10^{12})
Industrial	28.7	1,492
Electric Generation	20.2	1,052
Transportation	16.6	864
Residential	16.4	853
Commercial	8.7	452
Government and Others	9.4	487
	100.0%	5,200

Coal is of particular interest to Pennsylvania. During 1973 Pennsylvania used 80.7 million short tons of coal. This use was distributed as follows:

Coal Consumption By End Use

V. c.		%		TONS (short)
Steel	25.3%		20.4	
Other Industry	17.7%		14.3	
Total Industry		43.0		34.7
Electricity		42.0		33.9
Commercial		6.0		4.8
Residential		1.8		1.5
Government and Others		7.2		5.8
		100.0%		80.7*

* Total Production 82.5 X 10^6 Tons
1.8 X 10^6 Tons EXPORTED

Pennsylvania's electric power generating stations rely heavily on coal as a fuel; 81% of the production coming from coal fired stations.

TABLE VI

Electric Power Generation (1973)

VI. a.

Generating Fuels	%	BTU's (10^{12})
Coal	81	852
Petroleum	14	143
Hydro	4	42
Natural Gas and Nuclear	1	15
	100.0%	1052

Electric Power Use (1973)

VI. b.

	%	BTU's (10^{12})
Industrial	49.5	521
Residential	28.2	297
Commercial	18.0	189
Government and Others	4.3	45
	100.0%	1052

In summary, the 1973 Pennsylvania fuel consumption breakdown into categories was:

TABLE VII

1973 Pennsylvania Fuel Consumption Data

INDUSTRIAL:	%	BTU's (10^{12})
Coal	16.77	872
Petroleum	6.15	320
Natural Gas	5.77	300
SUB TOTAL	28.69	1,492
ELECTRICITY:		
Coal	16.38	852
Petroleum	2.75	143
Hydro	0.81	42
Nautral Gas and Nuclear	0.29	15
SUB TOTAL	20.23	1,052
TRANSPORTATION:		
Petroleum	16.62	864
SUB TOTAL	16.62	864
RESIDENTIAL:		
Coal	0.73	38
Petroleum and Others	7.75	403
Natural Gas	7.92	412
SUB TOTAL	16.40	853
COMMERCIAL:		
Coal	2.31	120
Petroleum	4.46	232
Natural Gas	1.92	100
SUB TOTAL	8.69	452
GOVERNMENT & OTHERS:		
Coal	2.81	146
Petroleum	6.27	326
Natural Gas	0.29	15
SUB TOTAL	9.37	487
TOTAL	100%	5,200

TABLE VIII

Fuel Consumption Projection (All Fuels)

VIII. a.	1973 (Actual) %	1973 (Actual) BTU's (10^{12})	1983 (Projected) %	1983 (Projected) BTU's (10^{12})
Petroleum	44	2288	42	3066
Coal	39	2028	40	2920
Natural Gas	16	832	14	1020
Nuclear	1	52	3	220
Hydro, Wood and Others			1	74
	100%	5,200	100%	7,300

Fuel Consumption Projection for Electric Power Generation (23)

VIII. b. Fuel	1973 (Actual) %	1973 (Actual) BTU's (10^{12})	1983 (Projected) %	1983 (Projected) BTU's (10^{12})
Coal	81	852	69.5	1250
Petroleum	14	143	14.1	253
Hydro	4	42	3.7	66
Natural Gas	1	15	0.5	9
Nuclear			12.2	220
	100%	1,052	100.0%	1,798

GSAC feels that effective steps can be taken to increase energy conservation to a significant degree by 1980 and to a greater degree by 1985. It is believed that, with appropriate conservation efforts, the added energy demands for transportation, residential use and commercial use can be reduced by 25% by 1980 and by an additional 25% between 1980 and 1985. If intensified efforts are applied to expanding the use of coal within reasonable environmental guidelines, some shift from petroleum and natural gas to coal might be expected by 1985 by industrial users and by electric utilities. This could amount to 25% of the added petroleum and natural gas demands between 1980 and 1985. Even with such conservation measures, energy demands are very large. If because of the difficulty of getting more petroleum an assumption is made that additional petroleum will not be available to Pennsylvania in the years ahead, greater use of other sources of energy will have to be made. For example, if the amount of petroleum - derived energy is arbitrarily held at the 1973 level and coal is called upon to assume a large part of the additional energy load in 1983, there would have to be up to a 27% increase over the projected coal figure of 2920 (10^{12}) BTU's for 1983. These additional BTU's from coal would have to be provided in the form of petroleum-like fluids for use by transportation, oil burners, etc. This would place an additional burden on the energy industry to provide sophisticated new liquefaction and conversion plants not now in place.

Looking ahead to the year 2000, it is clear that the Commonwealth faces formidable challenge in meeting its energy needs. As shown in Table IV the total energy demand in the year 2000 is expected to be 2.85 times the demand experienced in 1970.

C. Coal Reserves of Pennsylvania

This summary is taken verbatim from selected portions of reference (12) prepared by the Pennsylvania Geological Survey in cooperation with the U. S. Bureau of Mines.

For over a century and a half, coal has been a significant element in the public and private life of Pennsylvania. In the course of longterm planning, government agencies, the mining industries, and other groups find it valuable to have an estimate of the amount of coal remaining within the Commonwealth an its various counties.

Several estimates of Pennsylvania coal reserves have been produced previously, the last almost thirty years ago. This report revises those earlier reserve figures to January 1, 1970.

The summary figures for Pennsylvania are as follows:

In-place coal reserves:

Original - 102 billion tons
Mined out and lost - 22 billion tons
Remaining - 81 billion tons

Recoverable coal reserves (i.e. potential production):

Bituminous over 24 inches - 27 billion tons.
Bituminous over 28 inches - 22 billion tons.
Bituminous over 36 inches - 12 billion tons.
Anthracite over 24 inches - 8 billion tons.
All coal over 24 inches - 35 billion tons.

Revoerable stripping coal reserves (16 southwestern bituminous counties only): 3/4 billion tons.

The geographic distribution of Pennsylvania coals is shown in Figure 11.

Allowing for some excessive generosity in recoverable reserve estimates and the moribund state of the anthracite industry, the overall probably coal production potential for Pennsylvania is actually about 8 to 9 billion tons of readily minable deep-mine coal and 1 billion tons of readily minable stripping coal. At present rates of production this is sufficient deep coal for 150 years and strip coal for 50 years. In addition, there is about another 5 or 6 billion tons of marginal deep coal and another 1 billion tons of marginal strip coal.

About one-half of the readily minable deep coal is in Washington and Greene Counties with important additional reserves in Westmoreland, Somerset, Indiana, Fayette, and Armstrong Counties.

Most of the important stripping reserves are in Armstrong, Butler, Clarion, Clearfield, Somerset, and Washington Counties.

In spite of the presence of very large amounts of thick, high-quality, low-sulfur coal in the anthracite fields, the economics of production seem to be such that very little can be considered a likely source of future production.

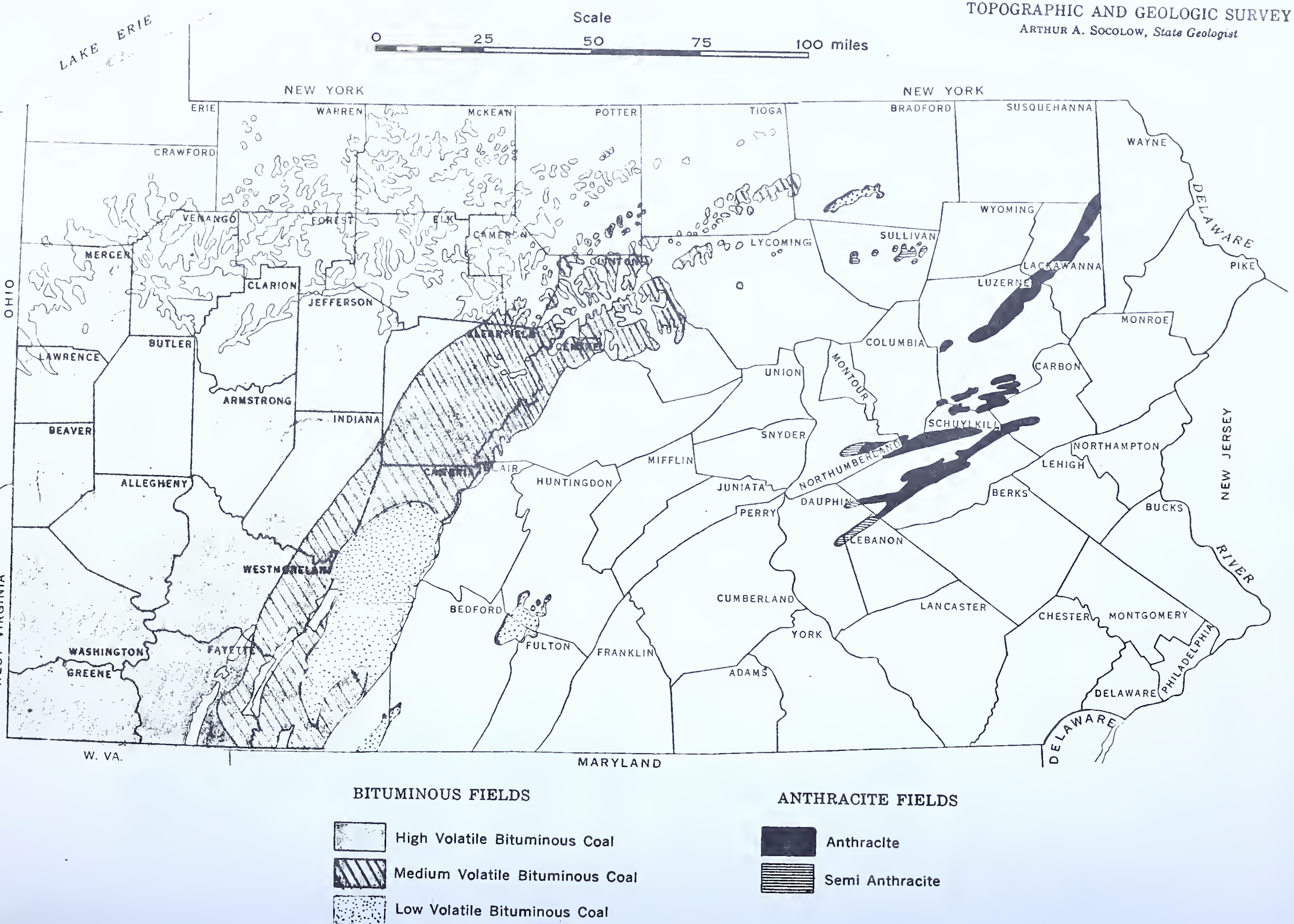
As opposed to in-place reserves, recoverable coal reserves are intended to give an estimate of the amount of coal which can be actually extracted and utilized. It has been found in practice that only 40 to 70 percent of the original in-place coal of an area can be recoverable by deep mining procedures, and perhaps 80 percent overall by strip mining. The remainder is permanently lost.

Usually it is customary to indicate potential recoverable reserves by taking the original in-place reserves and reducing them by a realistic loss factor. To use the in-place reserves shown in Figure 11 and reduce them by, say 50 percent will, however, yield an extremely high figure for recoverable reserves. The problem arises from the custom of considering seams as thin as 14 or 18 inches to be potentially minable. Although it is remotely conceivable that such thin coals might be extensively mined, the possibility in Pennsylvania is exceedingly remote.

Figure 11

DISTRIBUTION OF PENNSYLVANIA COALS

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF INTERNAL AFFAIRS
Genevieve Blatt, *Secretary*
TOPOGRAPHIC AND GEOLOGIC SURVEY
Arthur A. Socolow, *State Geologist*



V. Environmental Considerations

The extraction and utilization of various primary and secondary sources of energy for civilization produces a variety of impacts upon plants and animal life, both terrestrial and aquatic. In Pennsylvania the main primary sources of energy today are oil, coal, natural gas, atomic energy, water, and wood.

A. Water Power

Of these, the use of water to generate power or energy for man's use probably has the least environmental impact. The main impact of the use of water is that usually the creation of a dam is demanded. In the early days in Pennsylvania the dams were very small and did not severely impede the flow of the stream, particularly during periods of high flow. Today, however, hydroelectric dams are immense structures and have varied impacts upon the natural flowing river.

The slowing up of the natural flowing river and the settling out of sediments increases the nutrient load in this body of water. As a result, eutrophication often sets in and a reservoir, instead of being a clean, sparkling lake, becomes filled with rooted aquatics and floating algal growths. If this water is also used as a source of drinking water, taste and odor problems may develop.

There are many secondary effects that affect both plant and animal life in regard to the creation of a reservoir because recreation usually follows. This results in the increase in habitations, recreation facilities, and highways--all of which impact the natural environment. The degree to which such impaction takes place is largely determined by how well the use of the reservoir is planned as it relates to non-disturbance of the natural environment.

The building of a dam also affects the downstream river. Typically when the dam is used for power, particularly hydroelectric power, the water is released from low gates in the dam breast. This deep water is usually cooler than the ambient water and low in oxygen, often possessing no oxygen. This lack of oxygen or lower redox potential water has a soluble effect upon any heavy metals that may be tied up in the sediments deposited in the reservoir; thus downstream from the dam, water is usually not only cooler and lower in oxygen but also richer in trace metals. Since the aquatic life is largely dependent upon temperature and oxygen and the kinds of growth are greatly influenced by trace metals, the creation of a dam may have a profound effect upon the downstream aquatic life. It should also be pointed out that the clear water emerging from the dam has more energy in it than the sediment laden water which entered the reservoir. As a result, this clear water scours out the channel in an effort to attain a pattern of least work. Thus sedimentation increases downstream. Usually the operation of a dam controls floods, and whereas this control may be beneficial to man it may be quite detrimental to aquatic life in that the downstream river is no longer flushed during periods of high flow.

B. Natural Gas

Natural gas is one of the cleanest primary sources of energy. The refining of natural gas for use usually produces only a very local impact. However the use of atomic energy to release natural gas may have many types of effects that to date are poorly understood. The scientists of the United States Geological Survey have been investigating these effects. One deleterious effect may occur in the transmission of gas across country in pipelines. Should leaks occur the gas seeps out into the soil and could kill the covering vegetation and its supporting wildlife. It also, of course, kills the organisms that are in the soil. If these leaks occur within the stream they will kill the aquatic life in the immediate vicinity. Such areas have been seen by the Academy of Natural Sciences, and we have noted a wiping out of the aquatic life for many feet downstream. Fortunately, great improvements have been made in the structuring of pipelines and in the constant recording of the pressures within them so that leaks can be more quickly detected than in former years. Also, pitting effects of metals composing these pipelines can be mitigated by coating and cathodic protection. The careful maintenance of such pipelines can greatly reduce this hazard.

C. Coal

Coal is one of Pennsylvania's richest energy sources. However, mining, transportation, and preparing it for use have varying environmental impacts. Strip mining has one of the most severe aesthetic effects as well as damaging the natural vegetation and life in these areas. In strip mining the surface soils are peeled back and the coal is mined from seams which are relatively near the surface. Often this is carried out in areas of steep terrain.

At the present time Pennsylvania has probably the best strip mining laws in the country in that all strip mines must be backfilled; topsoil must be carefully saved; and once the backfilling has been accomplished and the topsoil returned, these areas must be planted according to regulations of the Department of Environmental Resources. Such planning is to produce grass and/or trees which will survive in these areas. A list of these has been prepared by the Department of Environmental Resources. In some cases the strip mining is to produce a more or less flat area whereas in regions of very steep terrain terraced methods of backfilling are employed. Although this method of obtaining coal causes severe eruption to the natural ecology during the time when strip mining is taking place, the restoration by backfilling of the former land terrain and the replanting of various types of plants greatly mitigates these bad effects. One of our great concerns should be that such backfilling does not create level areas, nor destroy natural drainage basins or watersheds in the backfilling of strip mine areas as this will impede the natural flow of water and the regeneration of ground water resources. Deep mines affect the overlying terrestrial landscape in the creation of refuse piles and also in the subsidence which sometimes takes place if the mines are not carefully constructed to mitigate this effect.

Pennsylvania law requires that refuse piles be formed in such a manner to prevent spontaneous fires from taking place and to provide cover so that erosion from them will not occur.

Both strip and deep mines may produce acid mine waste. This is one of the most serious effects on the aquatic environment of mining. This acid mine waste is due to the interaction of water with pyrite which is a common mineral found in association with coal seams. The action of the water on the pyrite creates sulfuric acid and this very acid water will kill the plants and animals living in the stream.

Since coal mining is often carried out in country of highest recreational value, the destroying of life in the streams is of severe recreational consequence. The effects of these acid mine wastes can be mitigated by treatment of these wastes before they have a chance to enter the stream by neutralizing their acidity with lime or other methods. Sealing of mines once mining is completed, or the careful backfilling of strip mines so that air and water cannot reach the exposed coal seams will greatly mitigate this effect.

The use of coal has various effects upon the environment. One is the air pollution caused by the burning of coal. Much burning, for whatever use, will free to the atmosphere nitrous oxides, SO_2, polycyclic hydrocarbons in small amounts and radioactive compounds. It is estimated that the amount of radioactivity produced by a fossil fuel plant into the atmosphere is quite similar to that produced by atomic energy for a similar sized plant. This, is, of course, if no accidents occur in connection with the atomic energy plant. Waste metals such as cadmium, mercury, and berylium are often eliminated in fly ash.

Gasification and liquefication of coal hold great promise for the State of Pennsylvania as primary fuel sources. In their formation the SO_2 and NOx are removed or greatly reduced and likewise the heavy metals and any fly ash forms are eliminated. This gas when burned is of very high quality. Undoubtedly it will be a very important primary source of fuel for the generation of electricity and for other use within the State.

D. Oil

Oil drilling is carried out to a minor extent in the western part of Pennsylvania. The main pollution problems relating to the production of oil is that brine water is often used and subsequently released for the separation of the oil. This brine water, because it has a very high conductivity as well as a high salt content may have a severe effect upon the aquatic life. This is particularly true when such brine waters are released into mountainous streams as happens in western Pennsylvania. For these reasons great care should be taken to keep such waters from entering the streams, and they should be deionized before this is allowed. If the forces of flow of the stream is such that dilution raises the conductivity only very little and likewise has very little effect upon the salinity, such might be allowable, but great care should be maintained in allowing such discharges into our streams not to change significantly the conductivity of the natural stream water.

In the distilling of oil for #2 fuel oil, gasoline, etc., usually crude oil or coal is used. As stated above, in the using of any primary source of oil or fossil fuels, NOx, SO_2, and various trace metals as well as radioactive substances are discharged into the atmosphere. Also polycyclic hydrocarbons are given off in very small amounts into the atmosphere.

Preparing or refining of oil often has other pollution problems--often heated water is discharged which may have small amounts of oil or phenol in it. Phenols are very toxic to aquatic life and oil may cause some problems, so great care should be taken that these substances are removed or reduced to safe quantities as set forth by water quality criteria regulations. The effect of heated waters is discussed below and the same general principles apply to heated waters whether they are released from refineries, other types of industries, or from power plants.

E. Uranium

The environmental impact of the mining of uranium for atomic energy fuels is similar to that of other mining activities. However the amount of uranium required is so small compared to the amount of fuel generated, and as a result the impact is also relatively small. The main problem is handling of radioactive fuels for their use in generating electricity or other kinds of energy uses. There are many problems involved. Great care has to be taken in the encasing of such radioactive fuels and in their transportation to make sure that no problems arise. Indeed, one of the most serious problems connected with the obtaining of radioactive fuels and in their use is in the transportation of fuel to the site and the transportation of spent fuel rods to areas where they will be regenerated. In the case of an accident the quenching of fuel rods could also introduce environmental radioactivity hazzards.

F. Generation of Electricity

Electricity is a secondary energy source but one of the energy sources most utilized today. When used it is a very clean fuel, but its environmental impacts in production and transmission are considerable. It is dependent upon a primary fuel source for its creation--be it water, coal, oil, or atomic energy. The production of electricity demands the creation of steam and the cooling of the condensers. This means that a large amount of water must be used for the cooling process. This is usually taken from some nearby surface water source--for example a lake, stream, or estuary. This water may be passed once through the plant or it may be recycled by the use of coolant towers or coolant ponds. One to two acres of pond per megawalt of plant capacity is usually required. Dry coolant towers utilize the air to cool the condensers and thus do not produce an impact on surface waters. The practicality of using these for large plants is in the development phase.

BWR and PWR nuclear plants currently in use require 60% more cooling water than fossil fuel plants. If the cooling water is recycled by the use of coolant towers, the demand for water from the surface water source is much less, being approximately that evaporated in cooling plus that used for "blow-down."

1. Effects of Coolant Towers

Increasing use is being made of coolant towers in modern electrical generating plants. These are generally natural-draft wet-type coolant towers, although forced-draft coolant towers are sometimes used. In either case the amount of water evaporated to the atmosphere is a small percentage of that taken in.

The evaporated plume is composed of pure water, and is wafted about by the wind. Typically it contains some tritium if nuclear energy is used as a fuel source. The affects that this plume may have on the environment are several. If there is air pollution--for example, SO_2-SO_4 in the atmosphere--the water in the plume will interact to form H_2SO_4 or various hydrated sulfur compounds. These compounds often cause severe burning when they come in contact with vegetation. In a similar manner the moisture in the plume may react with other air pollutants.

If the terrain is hilly or mountainous or if an inversion is severe the plume may be trapped and instead of being disbursed will accumulate. As a result, in winter roads may become icy due to the condensation of the plume. If large enough, the plume acts as a cloud, and shields out sunlight, which in turn may adversely affect plant life. However, if the terrain is flat and wind currents are strong relatively little adverse effect from the plume may occur. The important considerations are the terrain in which the coolant tower is located; the presence of air pollutants, and the weather characteristic as to temperature and inversions. Another important consideration is whether the watershed can afford to lose to the atmosphere the water lost by evaporation.

The drift plume contains the salts concentrated from the water, and the fallout of these salts is deposited on land. The dispersion of the fallout is determined by the wind pattern. Since the fallout from the drift results in the accumulation over time of these salts in the soil, one has to be concerned as to the use of the ground to be affected by such fallout as plant growth may be limited. For example, if the water is very low in conductivity the salt concentration will be small and might even be beneficial to the soil and plant growth. However, if the power plant entrains brackish or very hard water the concentrated salts in the drift plume may be deleterious to the soil structure and vegetation. This is particularly true if the drift plume contains chlorides. Coolant towers, because of their size, produce an aesthetic impact.

2. Effects of Condenser Cooling

Once-through cooling loses much less water by evaporation, but has far more thermal effect on the surface water resource than coolant towers.

Typically the heated water floats as it is lighter than the ambient water. However, if the entrained water is taken from a deeper and saltier layer of water it may sink if the heat is not high enough to counteract its greater specific gravity. Depending on the amount of water discharged, the way it is discharged and the flow characteristics of the receiving body of water the warm water may spread out over the surface and thus affect a large amount of the plankton organisms, or it may form a deep plume and create a thermal block to migrating organisms such as fish. If the discharge is made at the bank of the stream it may be caught in areas which have poor current circulation and as a result the heat builds up. This most often happens in tidal situations such as the upper estuary of the Delaware. If the flow of the stream is faster than the rate of discharge or the stream is very shallow, the warm water may flow in a fairly narrow band down one shore rather than mixing with the current of the river. As a result it does not form a thermal block but the heat is not dissipated for a much longer reach downstream. These thermal effects may be mitigated by a forced discharge which quickly entrains a large amount of water. The heat is dissipated by dilution rather than radiation, and a thermal block or a large area of heated water does not occur. This method of discharge is relatively new for large volumes of water and needs considerable study to understand its impact. It seems to be a desirable method where there are few thermal discharges and/or where the amount of discharged heated water is relatively small compared to the volume of water in the river. The effect on quickly entraining many organisms in the dilution process also needs study.

3. Thermal Effects on Rivers and Lakes

The effects of heat on surface waters and their organisms are several. It is well known that increasing the temperature increases the rate of diffusion and the solubility of many chemicals, and thus affects the chemical composition of water. It also effects the viscosity of water and therefore organisms tend to sink more quickly in warm water than in cool water. Higher temperatures usually increase bacterial activity and thus would speed up the mineralization process and create a more severe oxygen sag in areas of high nutrient loading such as downstream from a sewage plant.

The affects on algae, invertebrates, and fish are several. It is well established that all organisms have a range of temperature tolerance and within this is an optimum range which may vary in width and position with the age or activity of the organism. Small increases in temperature toward the optimum range may be beneficial. For example, raising the temperature a few degrees in winter may increase productivity and growth. However, this same increase in temperature in summer that raises the temperature above optimum is usually detrimental. If the temperature exceeds or is decreased below the range of tolerance, the organism may die. Whether it dies depends on the length of time of exposure. It has been found that organisms can be exposed to high or low temperature for a few seconds without lasting harm provided they are quickly returned to the ambient temperature in which they were living. The bad affect results from leaving them at the high temperature or the low temperature for long periods of time and acclimation has to take place. Therefore an entrainment through a condenser which exposes organisms for only a few seconds and the water is quickly returned to the receiving body of water will have much less affect than if the organisms were more slowly passed through the condensers and/or remained for an hour or more in an effluent canal. The smaller the rise in temperature the less harm produced, but the length of time of exposure seems to be the most important factor. The lower the temperature rise the more water has to be entrained for cooling; therefore, depending on the size of the receiving body of water and the type of organisms, a decision has to be made as to what rise condenser is best. If nuclear energy is used,a low rise condenser is also better if there is a chance of a sudden shut down. The reason is that sudden cooling of the water around the discharge may cause very serious fish kills if a zone of warm water has developed as the organisms cannot suddenly acclimate to much cooler water. Such areas of warm water should only be a few degrees above ambient.

Whereas entrainment and sudden exposures for short times may not kill organisms, it often temporarily alters physiological processes. However in many cases they quickly recover. Other affects of entrainment may be mechanical or chemical. Microorganisms are usually not affected by the mechanical aspects of entrainment, but larger organisms such as some zooplankton, juvenile fish, and eggs may be affected. The worst effect seems to be chlorination. The higher the chlorine concentration the worse this effect is. This may be mitigated by not using chlorine and using mechanical methods such as Amertap for keeping the condensers clean. If chlorine is used it should be applied at very low concentrations for longer periods of time.

Other temperature effects are produced by the alteration of natural temperature rhythms. Organisms have evolved over time to respond to diurnal and seasonal changes. Increases in temperatures which do not allow these shifts in temperature to occur may greatly affect aquatic life. For example, most organisms can withstand high temperatures for short periods of time provided that cooling at night occurs. Increases in temperature which hold the temperature above the optimum during the night as well as the day will have detrimental affects. Likewise, rises in temperature which will eliminate shifts in temperature, particularly in the spring of the year, may have serious affects upon reproduction. For example, the reproduction process of bass is stimulated by the water temperature passing from the low sixties to the high sixties in the spring of the year.

Disease or pests of desired organisms are often stimulated if temperatures remain higher for longer periods in the year than would naturally occur.

These affects may be mitigated if deep, cooler water is entrained rather than surface water. Under such conditions if low rise condensers (such as a 10°F condenser) are used the discharge water may be only a few degrees warmer than ambient and thus have much less influence on the receiving body of water. It is true that the oxygen may be much lower, but it rather quickly gains oxygen on discharge and if necessary orygenation can be increased by agitation. The plankton is usually much less in deeper water--particularly is this true for eggs and very young stages of organisms. Short retension time before returning to ambient conditions also greatly mitigates adverse affects as does discharging the water into the channel where mixing is thorough. The use of Amertap or other means than chlorine or heavy metal cleansers for cleaning also reduces harm to entrained organisms and organisms in the receiving body of water.

The affects of radioactivity under normal conditions of presently designed power plants seem to be minor. However, radioactivity should be continually monitored for accumulation in organisms in order that very small leaks can be quickly detected.

The effect on organisms of water intakes may be serious. This applies to industrial plants, refining or processing fuels as well as power plant intakes. Organisms are often drawn against intake screens which usually damages them if it does not kill them. Once the skin or scales or an organism has been subject to abrasive action it is more subject to disease. Therefore intake speeds should be kept as low as possible. The exact rate depends upon the density and size of organisms in the lake, stream, or pond. A speed of one-half foot per second or less is recommended. The deeper the intake usually the lesser the number of organisms entrained. However in winter fish often hibernate in deeper water, but a speed of a half foot per second or less will usually not entrain them.

4. Effects of Electric Power Lines

Electricity is transmitted by power lines. To date most of these have required the clearing of a strip of land which may extend for miles across the countryside. Such strips are aesthetically not pleasing and they also destroy some of the cover for game. To date underground transmission is not practical. However, the installation of towers by helicopter will greatly reduce clearing and improve the aesthetics as well as restoring much of the cover for game. Other plans for installations should be investigated such as running several lines so far as possible along the same path. The more electricity is used, the greater the number of transmission lines that will be needed. The use of higher voltages could substantially reduce the number of lines while at the same time increasing the tower size and right of way.

G. Summary Comments

From this discussion it is evident that hydropower, and particularly hydroelectric power, is the energy for man's use that has the least impact on the environment. However, as stated in the discussion, it has some impact. This primary and secondary energy source is relatively limited.

Fossil fuels impact the environment in their procurement as well as in their utilization. Coal in Pennsylvania is our largest primary source of energy. The terrestrial impacts from strip and deep mines are well controlled by our state laws. However, the impact of acid mine wastes is a severe problem and although its management has long been researched very effective ways of management have not been found. If we are willing to spend the money the acid mine wastes can be managed and the impact localized. Since mining areas are often in regions of great recreational value it is important that these acid waters be dealt with effectively so that their deleterious effects are only in a small region. This can be done by sealing and pumping the mines, and/or neutralizing the acid stream waters and containing precipitates. There are also other ways of treatment such as ion exchange beds. Further research toward the best means to solve the problem is needed.

The gasification of coal produces a fuel for many uses with no significant environmental impact. Although these methods of waste treatment and gasification of coal may appear to be expensive, if one counts the environmental and other costs they may be quite practical.

The main air impact of oil refining is in the use of the primary energy source for refining. There are, of course, aquatic environmental impacts in the procurement, transportation, and refining of oil. There is considerable technical information as to how to reduce these affects. In many cases laws and regulations are necessary to ensure the use of the best practical methods to mitigate adverse affects.

Considerable effort has been made by oil companies to remove oil and toxic substances from wastes before they are discharged so that the impact on the receiving body of water can be very little. A well run refinery using the best practicable methods may have little effect on the environment. Perhaps the greatest need is to greatly reduce the frequency and amounts of oil spills and the pumping of oily bilge water from ships into surface waters.

The use of gasoline for transportation creates a severe air pollution problem. The more effective use of gasoline, the use of pollution-reducing devices on exhausts, and the use of mass transportation will greatly reduce these problems.

The production of electricity creates air, water, and aesthetic environmental problems. However, there are several ways to mitigate these effects. One of the most important is to size the power plant to the restrictions of the environment. This means the use of fossil fuels, hydropower, and nuclear energy as a primary energy source where each are appropriate. Since fossil fuel plants use about 40 percent less water than nuclear plants per unit of electricity generated, this type of plant should be erected where the water resource is limited.

The ecological water problems resulting from the entrainment of water and subsequent heating are common to other industries as well as utilities. The impact of entrainment on organisms and the discharge of heated water from all types of plants can be greatly reduced by low intake speeds and various types of screens to deflect the organisms; deep water intakes; short retention time of water before it is returned to the receiving stream; low heat rise condensers; and a forced discharge of heated water into the channel where it is quickly mixed. Relatively little radioactivity is descharged into water by properly run nuclear plants.

Coolant towers may mitigate the effect on surface waters and are very beneficial in certain instances. However, as outlined above, they produce certain problems.

The air pollution problems vary with the type of primary fuel, these being SO_2, NOx, trace metals, and polycyclic hydrocarbons for fossil fuels and small amounts of radioactive pollutants for nuclear power plants. These air pollution problems with current knowledge can be greatly reduced but not completely eliminated. The important considerations are that they be reduced as much as possible; that they be discharged in a manner that will ensure that they are quickly dispersed; and that they be monitored so that any build-up can be quickly ascertained. Correct siting of power plants is one of the most important considerations.

The greatest potential environmental radioactivity problem of nuclear energy is in the handling of spent fuel rods and the management of wastes in case of an accident.

There are many proposed new methods for utilizing present fuel sources and the development of new resources. Among the more important are solar energy, geothermal power, oil shales, and nuclear energy such as fusion and the fast breeder reactor. Many of the environmental impacts concerning transmission, production, etc., will be similar to some of those for existing energy resources, others will have new impacts. To date we can only estimate these, and therefore they are not considered in this discussion.

H. Constraints on Fuel Use

This section is taken largely from a paper (20) by Howard W. Chapman, Associate Deputy for Air, Water, and Community Protection, Pennsylvania Department of Environmental Resources, delivered at the Pennsylvania Industrial Fuel Efficiency Seminar, held in Harrisburg, Pa., on August 22, 1973.

The mining, the preparation and the combustion of coal can cause severe damage to water, air and land if proper safeguards and techniques are not used.

Of particular concern today is the effect on air quality from the combustion of coal - particularly in reference to the Federal and State ambient air standards. The 1970 amendments to the Federal Clean Air Act mandated the Federal Government to develop and adopt nationwide primaary and secondary ambient air standards. Primary standards are based on health hazards, and secondary standards are based on public welfare issues. Under the amendments to the Act, the States, including Pennsylvania, were required to develop implementation plans to schieve the primary standards by 1975, and to develop implementation plans by July 1973 to achieve the secondary standards within a reasonable period of time. As a result, Pennsylvania did develop an implementation plan for achieving the primary air standards by 1975 and is now busily engaged in this endeavor. An implementation plan for the secondary standards has not yet been developed and so the July 1973 date mentioned above was not met. Negotiations on secondary standards are currently in progress between Pennsylvania's Department of Environmental Resources and the federal government's Environmental Protection Agency.

Regarding coal as a fuel, the two parameters of greatest concern are particulates and sulfur dioxide. The Federal Ambient Air Quality Standards on these are:

Particulate	Primary	Secondary
Annual Average	75 ug/cm3*	60 ug/cm3
Maximum 24 hr.	260 ug/cm3	150 ug/cm3
Sulfur Dioxide		
Annual Average	.03 ppm**	.02 ppm
Maximum 24 hr.	.14 ppm	.10 ppm
3 hr.	---	.50 ppm

From the above, it will be noted that the secondary standards are more restrictive than the primary standards which explains to a great degree the difficulty in drawing up secondary standards.

The implementation plan for the attainment of primary standards which Pennsylvania's Department of Environmental Resources drew up contained regulations which limited the emissions of particulates, sulfur dioxide, and hydrocarbons. These emission standards were designed to control emissions sufficiently to attain the national ambient air quality standards. In developing these emission standards for the three parameters, the Department used the technique of estimating and determining the existing air quality throughout the State by the use of sampling, emission inventories, and diffusion modeling techniques. A roll-back technique was then used to determine the amount of control needed to achieve the ambient air quality standards, and the emission standards were developed based on this information.

The application of these primary standards have placed constraints on the use of coal as a fuel in Pennsylvania as was intended in order to meet environmental requirements.

With regard to particulate matter it was determined that particulates should be controlled by a single statewide emission standard. The technology for controlling particulates is available, through the use of dust collectors, etc., but the cost may be high.

* Micrograms per cubic centimeter
** Parts per million

With regard to sulfur dioxide it was determined that it was not necessary to adopt a single emission standard for application throughout the Commonwealth since the studies showed that only the urban and industrialized areas had sulfur dioxide problems of significance. Therefore, the State developed and adopted a three-part sulfur dioxide emission standard. The most restrictive standard (0.6 to 1.0 pounds per million Btu input) applies in the Southeast Pennsylvania, the Allegheny County, the Beaver Valley, and the Monongahela Air Basins. A lesser restrictive standard (1.8 to 3.0 pounds per million Btu input) applies in the remaining eight of the State's twelve air basins. All areas of the State outside of designated air basins are covered by an emission standard of 4.0 pounds per million Btu input. The above emission standards apply throughout the State with the exception of Philadelphia County which has its own standard based on the allowable percentage of sulfur in fuel burned in that county.

Using the above outlined emission standards, an interpretation of the quality of coal which could be used without special treatment and meet the Federal ambient air criteria for sulfur and would comply with the State's emission standards are as follows:

1. In the four most restrictive air basins, the permissible sulfur in coal without flue gas control for an average Btu content coal would range from 0.4 percent fulfur to 0.65 percent.

2. In the remaining eight of the air basins, the maximum sulfur content could range from 1.2 percent sulfur up to 1.9 percent.

3. In the remaining eight of the air basins, which is over 85% of the State's area, the maximum sulfur content could be approximately 2.5%.

Also of interest to Pennsylvania is the prevention of ecological damage caused by the mining of coal, both deep and surface. A specific problem has been that of acid mine drainage. The hundreds of miles of acid streams in the State are primarily due to abandoned deep mines where none or improper techniques were used to seal the mine to prevent acid mine water from escaping, and from surface or strip mine works where improper drainage and backfill techniques were used.

Acid mine drainage can be prevented by keeping water out of the mine by recognizing and avoiding areas where geologic factors indicate high permeability; by treating the pollutants in order to remove or neutralize them before discharging the water; and, by sealing the mine after mining ceases to prevent the formulation of acid. Coal processing can be a major source of pollution if the waste water is not treated properly. Usually, the only treatment required is pH adjustment and sedimentation. The disposal of the coal refuse must be managed properly or it can become a serious source of water pollution.

Pennsylvania has had a strong law and outstanding enforcement of coal strip mining for many years, particularly since its landmark strong strip mine control bill of 1963 was passed and was further strengthened by subsequent clean streams legislation in 1965 and 1970. Complete contour backfilling is now required at most mines (a few exceptions where terrace backfilling is permitted), and a highwall has not been allowed to be exposed after reclamation since 1964. All drainage water from the strip area must be collected, neutralized and run through settling basins. All top soil must be preserved and placed on the backfilled areas as a final earthmoving step prior to planting the area with grasses to control erosion. The Pennsylvania coal strip mining industry has not only survived under these rigid requirements, but has done it in the face of competition from adjoining states where the requirements are less rigid. Since 1963, the number of strip mine operators in Pennsylvania has increased from 357 to 381, and the annual tonnage has increased from about 24 million to 27 million. Pennsylvania's early action to manage strip mining may have averted public demand for stopping strip mining altogether as has been the case in some states.

From the energy reports that are available, it is apparent that the Nation must look to coal as its major source of energy for the near future. From the President's energy message and from other reports, it is apparent that the Federal Government will vastly enlarge its R & D effort to develop and improve technology to cope with the sulfur problem. As indicated above, the Environmental Protection Agency does not plan to require the States to establish dates soon for meeting the secondary standards. It remains the policy of EPA and the State to meet the health-related primary air standards by 1975. It is hoped that, through the combined actions or developments relative to conservation, redistribution of low-sulfur fuel, and technological developments, these standards can be achieved by 1975--and Congress is not required to give an extension.

The primary ecological concern relative to the use of fuel oil is the sulfur dioxide problem, and the same emission standards prevail that were presented for coal. The combustion of gasoline and diesel fuels in automobiles and trucks pose an entirely different type of problem. The problem is being addressed by the Federal Environmental Protection Agency in limiting emission from the exhaust pipes in new cars. In addition, states are required to develop transportation strategies to reduce the number of vehicular miles travelled in cities where the ambient air standards are being exceeded due to automotive exhausts.

The use of natural gas has few ecological constraints as it burns cleanly, leaving few waste products.

Nuclear reactors are becoming increasingly important in the production of electricity. In Pennsylvania there are fourteen such nuclear power plants in operation, under construction, or announced for construction. There are considerable ecological constraints to obtaining electrical energy from nuclear power. Adequate planning and careful engineering are required to avoid or offset ecological problems from nuclear power reactors. In BWR's (boiling water reactors), non-condensable gases are discharged through an off-gas system and by holding up these gases in charcoal beds, radioactivity concentrations can be reduced. In new reactors additional cryogenic distillation systems and selective absorption in organic solvents are now being considered for the noble gases xenon and krypton.

In PWR's (pressurized water reactors), the hold up of gases extends over 30-60 days. For air releases, engineered systems can be built which will make zero release a reality.

Turning to liquid releases, PWR's contribute the major quantities of radioactivity in the form of tritium, a radioactive form of hydrogen. Releases of tritium from PWR's are thousands of times more than from BWR's. Since tritium cannot be removed, it is released with the conventional water discharge. However, several new PWR's are designed to have no liquid effluents. Eventually the PWR coolant will have to be removed from the plant and stored out of man's environment.

Because of the potential for accidents (though very small) nuclear power plants are now sited in low population areas. This criteria is used to allow for the controlling of the population group in the event of large-scale releases of radioactive material to the environment. The Department of Environmental Resources has reactor emergency plans for each facility in the State and those on our borders. In addition, nuclear power plants must be built with engineered safety features to limit the consequences of accidents as well as to prevent them.

VI. Social-Economic-Legal Considerations

One of the important responsibilities of the State is to assure that its citizens have a continuous, economical, and reliable supply of energy with due consideration for the protection of the environment and the conservation of natural resources. Such a supply of energy is vital for the health, safety, and comfort of the people of Pennsylvania, and for industrial viability with its associated opportunities for employment in the State. Energy means jobs. In the past many industries have left or failed to locate in Pennsylvania for a variety of reasons affecting their economic position; it is imperative that we do not allow the lack of energy or relative high cost of energy in Pennsylvania to become another reason. With wise planning it should be possible to mitigate many of the seemingly large problems arising from the interaction of energy requirements and protection of the environment.

Pennsylvania has a number of energy intensive industries within its borders; e.g., steel, aluminum, glass, cement, etc. As the price of energy rises, the costs of producing these basic materials will also increase. The relative increase will depend on the relative energy requirements for their production. This will affect the price of these materials with respect to others which might be substituted for them, perhaps, changing the market considerably; thereby affecting the economic health of these industries in our state. It is reasonable to assume that nonindustrial users will be equally affected within Pennsylvania and in our neighboring states with respect to domestic heating, prices of gasoline for transportation, etc., except for differences built in by different state tax structures.

With respect to power plants, we have a particular problem in replacing high sulfur fuel with low sulfur fuel of any form. If environmental law prevails, we can be in a very serious position with respect to providing or meeting our demands for electricity. This would have a major impact on industrial activity in the state, we assume that residential use would take priority.

As the price of gasoline rises, lower income groups who reply on the automotive vehicle for going to and from work will be regressively affected with respect to the higher income groups. In addition, the impact on leisure travel will be large, as 40% of our gasoline is burned in this manner. This would affect the resort areas of Pennsylvania considerably - winter sports, hunting, fishing and boating.

A. Conflicting Needs

A reasonable part of the present energy problem has to do with environmental regulations, especially, the federal requirements with respect to sulfur. This has caused a very rapid switch out of coal to low sulfur oil and to gas.

Large step changes in environmental standards can cause severe economic and social upheavals which are neither desirable nor necessary. Environmental control standards are needed, but their imposition must be on a time scale consistent with the ability of technological developments to cope with them.

In addition, there must be means for allowing variances at existing installations for reasonable periods of time until transsition from existing practice to desired practice is effected. Further, environmental controls need not be applied uniformly at all locations at the same time to be effective. While eventually all polluters must be required to comply with regulations, action is most effective when it is applied first where it is most needed. There are many small towns and rural areas where more time can be provided for compliance without severe injury to the environment.

At the present time, there are several other energy problems moving in parallel. One has to do with the present difficulty in meeting electrical power demands. This is due, largely, to delays in getting new plants on line; i.e., planning that took place five or six years ago did not take into consideration delays in construction, etc. due to environmental intervention. Presumably, this sort of delay will be brought under control as utility company planners become familiar with environmental impact planning requirements and new siting procedures. However, we will still be in a relatively poor electric power reserve situation for several years. We also have a shortage of clean liquid and gaseous fuels. Part of this shortage is due to the switch from high sulfur coal in industry and central stations to oil and to gas. A good part of the shortage of gas results from the capacity of our existing well and pipeline system to supply. The gas industry has not been an attractive investment in the last few years. Therefore, investment in proving reserves and increasing capacity has not kept pace with increasing demand. This is likewise true for refinery capacity and oil pipeline systems.

Federal and state actions have led to delays in bringing new facilities on line. Over the long run, these situations could be rectified by appropriate national and state policies. However, in the short run, we seem to have a problem for which there does not appear to be a solution short of relaxing SO_2 requirements so that more coal can again be the fuel of choice.

We entered the winter of 1972-1973 short on heating oils because of both unexpected increased demand for gasoline and higher profitability in producing gasoline. Refineries were producing gasoline for longer than usual. This meant that we were likely to enter the summer of 1973 short of gasoline stocks further aggrevating that problem because of our poor heating oil position now.

The country, as a whole, is short of storage facilities for liquid and gaseous fuels. Pennsylvania has a number of such facilities but needs more of them to better balance supply and demand. The Commonwealth should promote their development and construction by providing incentives for private industry to build them. The state itself might also consider developing them or at a no cost or a slightly profitable basis to itself as a service to industrial, commercial and residential users of these fuels. In the near future, the country is going to have to import more fuel because developing alternatives will take several years, even if they become allowed under revised environmental law. This means that we are going to have port facilities, as well as, pipeline and refinery capacity if this economic development is not to go elsewhere. If this does not happen, demand will not be met. Consumption cannot exceed supply.

B. Public Education

The general public is not well aware of the nature of the various energy problems facing us. It would be useful if the Commonwealth were to undertake an extensive public education campaign to inform its citizens of the nature of the various energy supply problems facing the Commonwealth. The state could also use its authority wherever it has it, as such, to promote public education with respect to efficiency of devices utilizing energy. If the state had authority, it could provide tax incentives, etc. to industry and commercial users for more efficient utilization of various energy sources. This may require a Constitutional Amendment or new Legislation or both.

C. Tax Incentives

The Commonwealth has various possibilities for controlling energy usage through taxation and tax credits, incentives to become more efficient, penalties to cut usage; for example, the tax on automotive fuels could be considerably increased if this were deemed useful as a means for rationing available gasoline stocks. Taxing truck fuels could, perhaps, move truck transport onto rail. However, this would have to be done on at least a regional if not a national basis in order to be effective. However, getting considerable freight and goods movement out of trucks onto rail would make available considerable fuel for domestic heating. This might also be accomplished by the Interstate Commerce Commission changing its freight rates. This could be accomplished if enough states were in agreement and brought pressure to bear on regulation changes.

It is difficult for the state to act on its own with respect to national policies as many of these would have to be done on a large scale, geographically, to be effective. Some relief could be had by allowing the use of higher sulfur coals than presently called for. However, again, this would require federal action to reduce standards or to permit selective imposition of the standards at the local level. If the Commonwealth is to begin enacting its own legislation with respect to environmental controls aimed at energy usage and incentives and disincentives with respect to usage of various sources, then it will have to staff itself with competent analytical people in the social, political, technical, economic aspects of energy and how energy pricing and availability will have second, third or fourth order impacts.

VII. Energy Research and Development Needs Important to Pennsylvania

Energy problems have increased in Pennsylvania during the recent past, and there is evidence that such problems will continue, or grow worse, in the future. There is a complex interrelationship between energy supply and utilization, and conservation and environmental considerations. To clarify the issues and develop sound bases for future technical and political decisions on energy problems will require an active research and development program. Such a program must cope with many problems.

A. General Considerations for a State Energy R & D Program

Many of the policies which have an impact on the energy situation at a state level are formulated at the federal level. For the most part, states merely comply, or attempt to comply, with federal policy after it is enacted without contributing any input to policy making. Inasmuch as these federal policies do affect us, the states should, in turn, be affecting the policies. Ways of channeling policy input from the states to the federal government hence should be investigated at an early stage.

The amount of money that the Commonwealth is likely to have to devote to research and development on energy will be small. Therefore, it ought to adopt, as a basic policy, to use this to secure matching funds from either industrial or federal sources or both when supporting research work.

The Commonwealth should be careful not to spend its money in areas supported by federal funds except on supplementary or complementary activities of particular importance to the state. Federal studies are not likely to deal with specific energy problems of individual states. Even in specific hardware developments; e.g., in coal gasification or liquification, the federal government is not likely to deal with special problems that arise because of the characteristics of particular local coal which can be very important to a state's economy but not significant on a national sense.

It would seem that, initially, some of the money that the Commonwealth might effectively spend in this area would be to better establish the nature of the state's energy economy. What are its energy intensive industries? What is its balance of trade in energy and manufactured products with respect to other parts of the country? This affects local jobs, housing, etc. What resources does the Commonwealth have with respect to its competitors (mainly cost)? What technical, scientific, political, economic, social impediments are there that would prevent the Commonwealth from capitalizing on its relative strengths? It is not likely that federal research is going to be very useful here. This would have to be done with state money.

It would seem that a considerable amount of the money available, initially, ought to be used to establish the nature of the Commonwealth's problem. This would then make possible more rational the support of selected scientific and technical research and development programs that aren't covered with federal money and that apply to our particular advantages or disadvantages.

Another aspect of this problem would be for the Commonwealth to have somewhere in its structure - perhaps, in the Office of Science and Technology - additional staff that would stay abreast of national and international developments in the energy area with respect to energy, resources and the environment and have a good understanding of the Commonwealth's needs; thereby, being able to advise the Governor of emerging problems or actions that he might take.

It is probable that one of the most effective things that the Commonwealth could do once it better understands its problem, needs and advantages, would be to use economic incentives in addition to research money to promote the development and implementation of certain technologies within the state rather than elsewhere. For example, if significant, clean fuels from the coal industry could be established in the Commonwealth and could also provide the basis of the plastics industry.

B. Specific R & D Activities Applicable to Pennsylvania

The topics suggested below were developed by an energy panel in the Workshop on R & D Priorities in Pennsylvania conducted by the Center for the Study of Science Policy of the Pennsylvania State University in Harrisburg, Pa., on March 5, 1973 (13). The panel included a number of GSAC members whose input is included. These suggestions formed the bases for a number of the recommendations presented earlier in the report and are included herein as further background information.

1. Research into the interaction between the supply of and demand for energy, with particular focus on the impact that alternative pricing systems might have on supply and demand.

2. Research on reducing the energy requirements of existing products.

For example, carbon steel motors are widely used in homes and industry to operate appliances and equipment. These motors run hot and consequently use electricity inefficiently. The development of an alternative form of motor which operates more efficiently would reduce the demand for energy.

3. Research on the effects that modified state building codes which contain provisions regulating insulation, glazing of windows, etc. would have upon the demand for energy.

4. Research into the effects that federal policies have upon the energy situation in Pennsylvania.

5. Research into the energy implications of existing federal air quality standards for SO_2 and NO_x.

One of the factors which helped to precipitate the energy shortages of this past winter can be traced to air quality regulations which have been put into effect recently. There is a general feeling that sulfur dioxide and other air quality regulations have been arbitrarily established at given levels in response to an emotional feeling that the air we breathe should be kept clean, rather than as the result of scientific decisions. If this is true, the energy situation may be exacerbated by unnecessarily rigid limitations.

6. Research and development to define scientifically sound air quality limitations in terms of specific geographic areas as well as at the stack point.

7. A survey of on-going regional development projects to determine the pattern of future energy demand.

8. Research on the development of safer an more economical systems of underground recovery of coal--especially for seams less than thirty-six inches thick and/or pitched seams--as well as for methods of surface mining that are compatible with society's wish to avoid strip mine damage.

The most economic seams for mining are thirty-six inches or thicker. Pennsylvania has many seams that are thinner than this, but the techniques for coping with these thinner seams are not readily available. Also, many of Pennsylvania's coal seams are pitched at severe angles, and better techniques for coping with pitched seams are needed.

9. Research on the beneficiation, liquefaction, and gasification of coal in Pennsylvania.

The use of Pennsylvania's coal may be limited by its sulfur content. Two basic approaches are used to control the sulfur in coals. One is to remove the sulfur from the stack gases following combustion. The energy panel questioned the value of Pennsylvania's supporting work on stack-gas clean-up. Instead, the panel favored the second approach, that of removing sulfur from the coal at the input stage or prior to combustion.

10. Continuation of existing annual data series on the state's coal resources.

11. Identification of potential sites for liquefaction and/or gasification plants.

12. Research on the characteristics of the coal labor market.

13. Research on improved techniques for deep-well drilling of petroleum.

14. Research on achieving greater recovery of residual oils.

Pennsylvania is an active producer of both oil and gas. There are presently about 60,000 operating oil wells in the state. However, many of them are stripper wells, the average production of which is 1/2 barrel per day. This compares with average daily yields of 5,000 to 10,000 barrels for Middle Eastern wells. During the past year, more than 1,000 oil and gas wells were drilled; about 700 of these wells were dry. Of the 300 wells which were not dry, less than 10 percent are economically viable. The potential for increasing production of oil in Pennsylvania lies primarily in the potential for secondary or tertiary recovery from oil fields which have already been tapped. Between 40 and 50 percent of all known reserves remain in the ground after pumping by normal methods because there is either insufficient pressure to extract additional oil or the remaining oil adheres to grains of sand. A technique for recovery of this oil has not been perfected.

15. A study of the economic and environmental consequences of oil drilling in Lake Erie.

There is a significant amount of oil underlying Lake Erie. Offshore drilling in Lake Erie has been prohibited within the boundaries of Pennsylvania. However, Canadians are drilling wells in the portion of Lake Erie lying within their boundaries.

16. A study of the effects of an incentive program designed to encourage deep-well drilling for gas in Pennsylvania.

Pennsylvania is known to have reserves of gas. However, these reserves generally lie at depths of 6,000 to 8,000 feet. Deep areas with potential for development have been identified, but the risks are high. It is estimated that the cost of drilling deep wells range from $150,000 to $500,000 per hole. These same costs apply in other states where the risks are not as high. Consequently, oil companies are unwilling at the present time to undertake deep-well drilling in Pennsylvania.

17. A study of the economic and environmental consequences in Pennsylvania of deep-water ports for petroleum.

18. Identification of suitable sites for nuclear power plants.

Forecasts which have been made concerning the long-run supply and demand for energy project a shift away from primary reliance on fossil fuel sources in favor of nuclear, solar, or other forms of energy. At the present time, there are a number of nuclear power plants operating in Pennsylvania. The future situation with regard to nuclear plants depends on a number of factors, including the availability of acceptable sites. While the federal government reserves the right to approve or disapprove a potential site, the proposal is developed by the individual utility. The availability of potential sites is constrained by a number of criteria including geologic requirements and the supply of water for cooling purposes.

19. A study of the effects and extent of effects of increased water temperatures resulting from the discharge of cooling waters from

power plants on Pennsylvania's streams.

The water which is used for cooling purposes in the generation of nuclear or fossil-fueled power raises the temperature in the receiving body of water if it is not cooled prior to discharge. This thermal effect has received a great deal of attention in terms of the potentially harmful effects on the flora and fauna. Recent studies which indicate that these effects may be different from those assumed in the past have been completed in other states.

20. A study of the potential impact of a uranium enrichment facility in Pennsylvania.

In the past, uranium enrichment has been carried on primarily by the federal government. This situation is on the verge of changing, however, with a number of private companies preparing to possibly undertake such activities. As is the case with deep-water ports, there is potential for developing a uranium enrichment facility in Pennsylvania.

21. Research on the incineration of waste and methods for recovering the heat from such waste.

There have been proposals to do exactly this, but the problem seems to be related to getting guaranteed access to the waste rather than the technical problems of burning it.

22. Study of the question of what happens if energy shortages materialize.

Questions on the establishment of priorities for energy rationing, the implementation or administration of controlled distribution of energy, and the impact of alternative policies were raised, but unanswered. The panel agreed on the following:

a. A study should be conducted to determine priorities which should be followed and the impact of alternative policies in the event of a severe energy shortage.

b. Also, efforts should be undertaken to develop methods for educating and motivating people to understand the need for conservation of energy.

VIII. Assessment of Options

In this section extensive use is made of Appendix 1 of Reference (14) which reported on the Governor's Briefing on Coal Conversion Processes held in Harrisburg, Pa. on January 25, 1973 as part of GSAC's consideration of Pennsylvania's energy problems. Reference (15) was also used.

As indicated earlier, in perhaps 15 years a variety of new processes can provide us with substantial amounts of clean energy from coal and nuclear fuels. Moreover, they should do so at costs competitive with the projected costs of other presently available clean fuels. But in the shorter term, there is no single course of action open that will fully satisfy both needs for energy and for meeting environmental requirements. We must, therefore, make use of a number of temporary expedients during the next 10 to 15 years, and indeed such expedients are available. However, we shall only sail into calmer waters in 10 to 15 years if vigorous research and development are accelerated now.

Figure 12 has been prepared to illustrate the times at which various options regarding present and future sources of power can become available even if appropriate research and development programs are accelerated now. As shown in this chart, most of the new developments expected from such research and development work can have a significant impact on our energy problems only after 1985.

Specific consideration affecting both the short-term and medium-term energy situation are discussed in the following two sections. These discussions are then followed by an evaluation of the related energy distribution problems and providing energy for transportation.

A. Short-Term Considerations Affecting Energy Production

1. Fuel and energy consumption for electric power generation accounted for only 26.3% of total energy use in 1970 (a national average). Of this 26.3%, 0.3% came from nuclear, 4.1% from hydroelectric and 21.9% from fossil fuels (coal 12.1%, gas 6.2%, oil 3.6%). Direct industrial, commercial and domestic use of fuel is much greater in aggregate.

2. Appendix 1 of Reference (14) reports that the overall conversion of the thermal energy of fuels via electricity into effective heating of homes is particularly low, and should be discouraged as it compounds our energy problems. However, other studies show that this is not necessarily so. In one study (21) the total electric home was found to use about the same (and in some cases less) raw energy per square foot than combination fueled homes.

3. The low cost of fuels and energy in the past has encouraged many wasteful practices. In particular, except where heating was by electricity, there has been no incentive for builders to install good insulation. Better insulation can save as much as 15% of fuel consumption. State standards could be set for new buildings, and

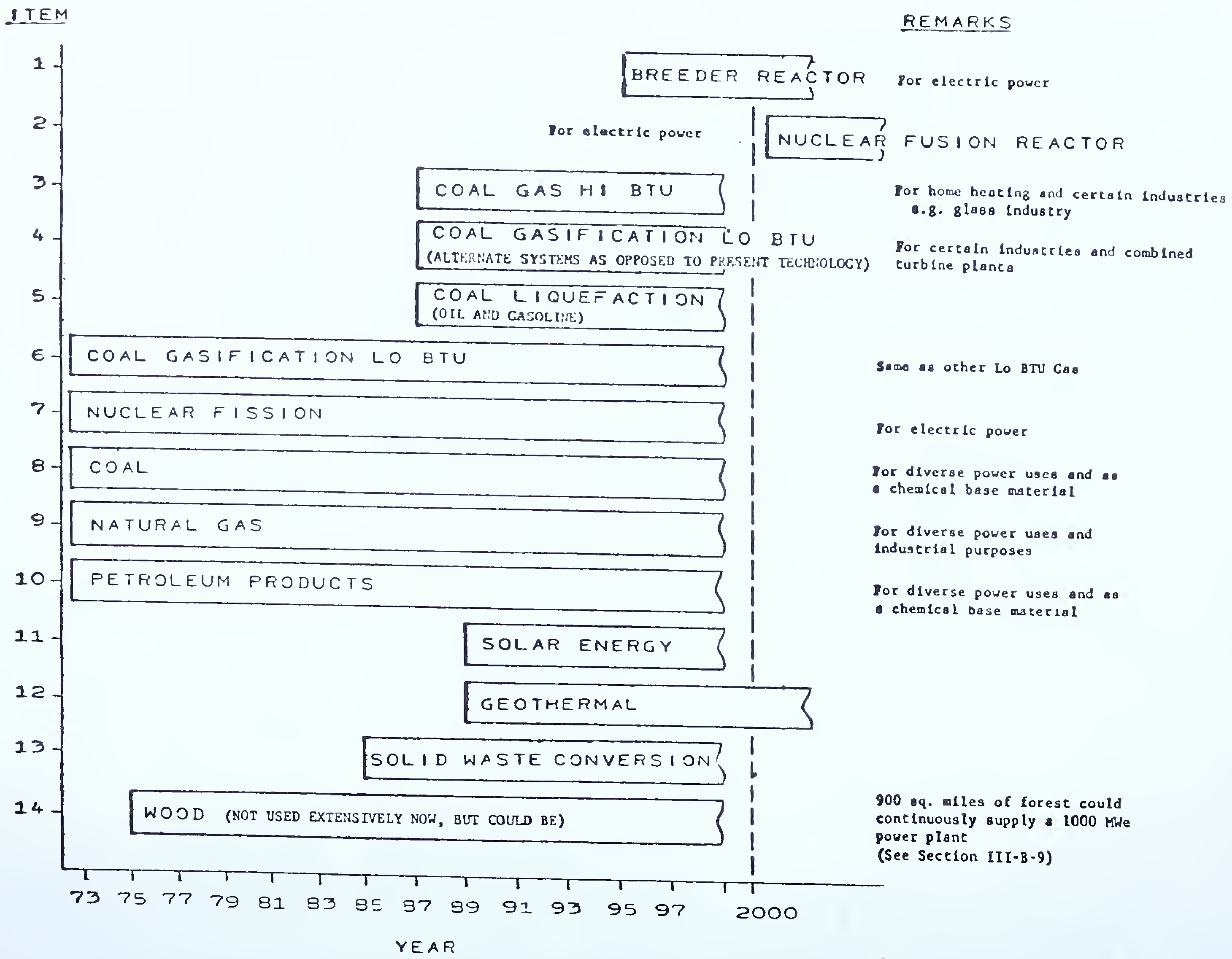


FIG. 12. TIMES AT WHICH VARIOUS ENERGY TECHNOLOGIES MIGHT BE AVAILABLE

tax relief or other incentives could be used to encourage the improvement of insulation in existing buildings. Many high temperature industrial furnaces have very low thermal efficiency, because the cost of wasting fuel has been less than the cost of installing heat exchangers and good insulation. This is less so in heavy industry, whose fuel costs are higher, but there is still room for improvement.

4. Gas-fired, domestic furnaces and ranges and industrial appliances are usually fitted with pilot lights as means of ignition. Overall, the pilot lights consume about 8% of the total fuel used for the appliances. Other safe means of ignition are available which do not waste fuel.

5. A 250 megawatt power station burns about 2 tons of coal per minute, and passes up the stacks some 1-2 million cubic feet of gas per minute (over 2 billion cubic feet per 24-hour day). It is because of this enormous volume of gas that no engineer would contemplate for a minute installing stack gas scrubbers if he did not have to; every cubic foot has to be brought into efficient contact with a solid or liquid absorbent to remove to an acceptable level the 500-1500 parts per million of sulfur dioxide present.

   TVA and Kansas City Power and Light Company already have full scale experimental stack gas cleaning plants which are used for testing processes and gaining operating experience. No satisfactory system has yet emerged in these plants. The optimistic estimates of the potentialities of stack gas cleaning to be available soon have mostly derived from designers of processes and manufacturers of the necessary equipment. In reality, one might expect to have a proven system working successfully within 5 years, and the experience gained would then guide the design of new installations. It is still possible that the costs will prove prohibitive, particularly when stack gas cleaning is added to an existing power station. For a new power plant, stack gas cleaning will add about 20% to the overall cost of construction, as well as adding to running costs.

   With present technology, the average residence time of the gas in the scrubber has to be about 30 seconds, which means that the scrubber has to be very large because of the enormous volume of gas to be processed. What is needed is a very efficient absorber that does not get rapidly plugged with sulfur, and a better reactor design, so that the necessary residence time can be reduced.

   As noted above, electric power generation accounts for about one-fifth of total fuel consumption. The balance of consumption relies mostly on oil and gas. If, as these become in short supply, there is conversion back to coal for industrial process heating, there will be further problems of stack gas cleaning, though these will not be so severe with smaller units.

6. Coinjection of lime or dolomite with coal has been tested in the

U.K. as a means of reducing sulfur emissions in power stations of the currently used type. This expedient does not reduce emissions by more than about 20%, but this would be sufficient with some marginal coals. However, larger precipitators may well be needed to remove the particulates from the stack gas.

7. A significant amount of Pennsylvania's bituminous coal is converted to coke for use in making steel. Actually Pennsylvania is the leading coke producer in the United States; it supplies 27.7% of the nation's coke. Approximately 13% of all the energy used in the state comes from coke and the coke-oven gas which is produced in the coking process. Hence, it is important to maintain a viable coking industry to support steel-making in Pennsylvania as well as other parts of the nation.

   Coal used for this purpose must be of metallurgical grade. Pennsylvania is an important supplier of such coal and must maintain or increase its output to help fill the shortages of metallurgical coal which are developing in the United States.

8. If the prices of natural gas and oil are allowed to rise, there is no doubt that more of both will be found within the continental U.S. This is only a short term solution because exploration will become more costly and yield diminishing returns.

9. Pennsylvania anthracites are relatively low in sulfur (0.5-1.5%), and it may be desirable to make use of them for industrial heating and steam generation, since little sulfur clean-up would be necessary. There are objections, however:

   (i) Anthracites are relatively costly to mine, and some of the mines are now flooded.

   (ii) In specially designed equipment, anthracite can be burnt quite satisfactorily. In equipment designed for bituminous coals, one could only, with present technology, use a blend of anthracite with bituminous, because of the low reactivity of anthracite.

   (iii) The efficiency of electrostatic precipitators in removing anthracite ash from stack gas is rather low.

   Nevertheless, in the circumstances, the possibilities should be explored.

10. Even though all possible advantage is extracted from the above measures, it is likely that some reliance on imported supplies of gas and oil will be necessary for some years. As competition with Western Europe, Japan, Australia and other countries for supplies becomes more serious, prices will rise and the balance-of-payments crisis will become intolerable, if overseas supplies continue to be relied on.

B. Medium-Term Options for Energy Production

1. Power Generation

It has been realized for some time that combined cycle power stations would have a much higher thermal efficiency than the stations presently in use. In these, a low-sulfur oil or a cleaned gas would be burnt under pressure, the hot combustion gases would drive turbines directly, heat remaining in the exhaust gases would be extracted in a waste-heater boiler and the steam generated would raise further electricity in steam turbines.

Full advantage of the system cannot yet be taken chiefly because materials of which to make the turbine blades are not yet available for service at the high temperatures required for high efficiency (2400-2600°F). United Aircraft and perhaps other caompanies are developing such materials for jet engine use, as well as power generation.

At any rate, here is a strong potentiality for means of power generation that would cause much less SO_x, NO_x and thermal pollution than present stations, and would be operationally more economical. If gas from coal is used as fuel, removal of sulfur will be far simpler than stack gas cleaning, because the volume of gas to be cleaned will be only 3-5% for equivalent power production. There is a case for building a plant now on this system, to gain experience in operation. It should be versatile enough so that better turbine blades can be fitted when better materials become available, and initially should use fuel oil from petroleum. During the briefing, it was pointed out that the Westinghouse Electric Company is indeed pursuing this course of action and that a 250 megawatt plant will be operating by 1980 (14).

2. Fluidized Bed Combustion of Coal

This system embodies a recent design of the combustor to be used in a steam-raising plant. Crushed or finely powdered coal is burnt in a "fluidized" bed, that is, a bed of particles suspended in the combustion air so that the gas-solid mix behaves like a liquid. For various technical reasons, this means of burning coal results in greatly decreased SO_x and NO_x emission and may be cheaper to build than present steam-raising plants. It is being developed by National Boal Board in Britain, though not yet on a large scale, and by Pope, Evans and Robbins, and by Esso, in the U.S.

The system has potentialities in the fairly near future for meeting the steam-raising needs of industry and perhaps also for space heating of large commercial buildings. In view of the potentialities of combined cycle power generation (#1 above), it does not seem worth developing very large fluidized bed combustors for this purpose.

3. Some General Remarks About Coal Conversion

There are three options: gasification to gas of low Btu content, conversion to high Btu (pipeline) gas, and liquefaction. There is no doubt that all three options should be taken, because of the differing needs of consumers and their location in relation to the point of energy production. Comparing liquefaction to a low-sulfur fuel oil with production of high Btu gas, for power generation, domestic and commercial uses, and industrial process needs, liquefaction is preferable because:

(1) Less addition of hydrogen to the coal is needed for conversion.

(2) Energy conversion efficiency is higher (75% compared with 60%).

(3) Much less water is needed (water is the ultimate source of the hydrogen for gasifications).

(4) Oil is easily stockpiled against peak loads, while gas is not.

(5) Oil can be pipelined cheaply; this has a lower cost per mile per Btu than pipelining gas, shipping coal or transmission of electricity.

(6) The cost per Btu is likely to be appreciably less.

(7) The product is safe to transport and store.

A disadvantage is that with present technology, removal of nitrogen is rather inefficient in liquefaction but can be high with gasification.

The thermal efficiency of producing low Btu gas is high and conversion costs relatively low. The costs of low Btu gas pipelining are very high and so the gas must be generated where it is to be used.

Table VII summarizes the options available for use of coal conversion processes.

4. Low Btu Gas

There are two processes that have been tested extensively on a commercial scale, though not in the U.S. Of these:

(a) the Lurgi process gasifies coal under about 20 times atmospheric pressure, which reduces the size of the gasification and combustion equipment and considerably reduces the cost of sulfur clean-up by reducing the volume to be scrubbed. It can only be used with caking coals, such as those of Pennsylvania, if the coal is pretreated, part of the Btu content being lost in the process.

(b) the Koppers-Totzek process can accept any coal without pretreatment, but operates at atmospheric pressure, so that the product gas would have to be compressed before any use is made of it.

Development of better processes is in progress. This approach could be valuable for industrial process heating and steam raising. Use of the gas for combined cycle power generation has been proposed and would be effective, but a fuel oil from coal would be preferable if nitrogen removal can be accomplished.

5. High Btu Gas

Many processes are under development and at least five pilot plants are being built; two of them, the Bi-gas and the Synthane, in Pennsylvania. Some of the processes require that caking coals be pre-treated, as with the Lurgi. This gas is the most convenient fuel to use for most purposes and it would be expensive for some present users to switch to an oil. The price of natural gas, unlike that of other fuels, has been regulated for many years at what many believe to be unrealistic levels. It is likely to prove the most expensive of fuels. If large oil tanks are installed, consumers to some extent may be able to stockpile in periods of ready availability, but this is not possible with gas. Most processes generate a low Btu gas first and then catalytically convert this to high Btu gas; this catalytic or "methanation" step has still not been developed to a fully satisfactory state.

6. "Solvent Refined Coal"

This process is being developed by the Office of Coal Research with Pittsburgh and Midway Coal Company, and Electric Power Institute with Southern Electric Generating Company. Two pilot plants are being built, one in Tacoma, Washington, and another in Birmingham, Alabama. These are being built to determine the economic feasibility of producing a solid or semi-solid fuel of reduced sulfur and ash content from coal. The product is pumpable at 160°F and higher but not at lower temperatures. At lower temperatures the process produces solids which can be in various size of pellets. These could be used as a household fuel with little ash and low sulfur effluent. It is not clear, however, whether or not it will produce fuels of acceptably low sulfur content from Pennsylvania coals.

7. Coal Liquefaction

The conversion of coal to a "synthetic petroleum" has been known since about 1925 and was relied on in Germany during the special conditions of the Second World War to produce essentially all the aviation gasoline needed for the war effort. Since then, the technology has been considerably advanced and "Project Gasoline", for which a pilot plant was built by Consolidated Coal Company with support from O.C.R., had the same objective of producing synthetic petroleum. However, attainment of this objective requires a large consumption of hydrogen, which is expensive. Recently, a more limited objective has been strongly advocated by some research groups: to use a minimal amount of hydrogen and a specially designed catalyst to convert coal to a low-sulfur pumpable fuel oil. Such an oil would be cheaper to produce and could be used for power generation, domestic and commercial needs and industrial processing. Remaining supplies of petroleum would be then reserved for transportation fuels and for chemicals.

Processes with the more limited objective are under development by Gulf Research and Development Company (Pittsburgh, Pennsylvania), U.S. Bureau of Mines (also in Pittsburgh) and Hydrocarbon Research, Incorporated (Princeton, New Jersey). The latter company is supported by a consortium of four oil companies. The processes differ in catalyst used and in reactor design, and are at somewhat different levels of development, but all have worked satisfactorily on a small scale. Gulf has designed its own multi-functional catalyst, while the others use commercial preparations. Reactor design present difficult engineering problems, and difficulty may be experienced in scale-up with all three concepts. Appraisal of the three concepts by an independent engineer would be helpful. No immediate plans for building a pilot plant exist. Nevertheless, with adequate support, liquefaction may well make a substantial contribution to energy needs sooner than gasification, because the equipment needed for the various unit processes of liquefaction can largely use existing and proven designs.

8. Multi-Purpose Coal Conversion Plants

With some liquefaction and gasification processes, large quantities of hydrogen will be required and there may be an unreacted residue or "char." The char can be used to generate hydrogen or can be burnt. It has been pointed out by staff of the Office of Coal Research that in these circumstances, it would be economic to have a multi-purpose plant in which by-products of one process would be consumed in another. The products of such a plant might be High Btu gas, solvent refined coal, and electricity. An input of 100,000 tons of coal per day would be needed, which presents large logistic problems.

The concept obviously has merit, but probably should not be attempted until the single-purpose conversion plants are well proven in large scale units. In the case of coal liquefaction to a medium-to-heavy fuel oil, hydrogen needs are low and so incorporation of the plant into a multi-purpose installation would be of little advantage.

9. Nuclear Power

In 1971, nuclear energy provided 0.3% of the Nation's total energy needs. The capital costs of nuclear power plants have proved to be much higher than initially anticipated. Present designs are not as efficient as new, modern fossil fuel fired power stations, although they are more efficient than many fossil systems now in use. Fast breeder reactors, now under development, will not only conserve uranium, but will permit the use of different concepts of thermal engineering, with the result that they will have much higher thermal efficiencies than present plants. Problems of radioactive waste disposal will still remain. But even when nuclear energy is making a considerably higher contribution than it does now, it will still contribute primarily to electricity generation, which provides only less than one-fourth of the Nation's energy needs. In the meantime, many nuclear reactors of the current type are being built or are seeking licenses.

C. Evaluation of Energy Distribution Problems

1. Electrical Transmission

As the demands for energy in the Commonwealth have increased the transmission of energy by electrical wires has followed the requirements of the consumer. Initially transmission was local in nature, each generating station transmitting its own power to a group of customers adjacent to it. The interconnection of generating stations began in the early period of the industry and has progressively increased to where not only generating stations of individual companies have been interconnected but companies have been interconnected and operate as groups. And now the groups have been interconnected into a nationwide grid whereby electrical power follows from border to border, east to west, and north to south.

The transmission voltages initially were at 2400 volts and progressively have increased as the loads have demanded additional power transferred to where today the highest voltage operating in the Commonwealth is 500,000 volts. The Pennsylvania-New Jersey-Maryland Interconnection initially operated as an interconnection of the Pennsylvania Power and Light Company, the Philadelphia Electric Company, the Public Service Electric and Gas of New Jersey. This interconnection was the Nation's first power pool.

As the generation of electricity has become more and more concentrated in larger units due to the demand of the public to remotely locate these large stations away from urban centers, more and more power must be transmitted to the centers of population over high-voltage transmission circuits. The increasing pattern of higher voltages has been necessary in order to transmit larger and larger blocks of power. These large transmission power lines have received considerable opposition from various local groups who have succeeded in delaying the installation of the lines as much as two to three years; e.g., the Delaware River crossing problem faced by the Delmarva Power and Light Company. Most energy transmission by electricity in Pennsylvania has developed utilizing alternating

TABLE VIII

OPTIONS IN THE USE OF COAL CONVERSION PRODUCTS

Energy Use	Electricity Generation	Domestic and Commercial	Transportation	Industrial
% of total energy used	26.3	24.5	25.2	32
Approx. efficiency of energy use	31	50	20	33
Possible fuels, in order of preference*	heavy oil	medium/light fuel oil	None (petroleum is best)	light and/or heavy/medium oil
	low Btu gas			coal (if burnt in fluidized bed combustors)**
	high Btu gas	high Btu gas		low Btu gas
				high Btu gas

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* The order of preference is based on cost, efficiency and ease of distribution. The order is, of course, arguable to some extent.

** For steam-raising only.

current, although some of the original power transmitted on a very local basis adjacent to generating stations was direct current at relatively low voltages. Today studies are underway to ascertain the feasibility of utilizing high voltage direct current lines in lieu of high voltage alternating current lines. These lines have the advantage of being able to transmit very large blocks of power utilizing less aerial space. However, it is necessary to install expensive equipment to transform the alternating current at either end of the direct current line and as such the economics will only justify the transfer on very large blocks of power over relatively long distances.

(a) Underground Transmission

Present technology precludes the utilization of underground transmission for bulk transfer of power from large generating stations through urban centers. The capital costs of high voltage underground transmission is ten to thirteen times more expensive than comparable overhead design at similar voltages. Five hundred KV underground cable technology is currently being assessed; however, its reliability for a modern electrical system has not been accepted to date. The transfer of electrical energy within the urban complex can be accomplished with underground cable at much higher capital costs, which must be paid by the rate payer.

(b) Summary

The need to site power plants at specific locations will require the development of energy corridors either under the auspices of the Commonwealth or by acquisition by the public utilities. The conservation of land requirements would indicate the development of an overall plan in the Commonwealth for energy corridors to transfer energy in the form of liquid, gaseous, or electrical energy. Presently available locations such as interstate highways and turnpikes which have already consumed the land might be considered for this purpose; existing and abandoned railroad rights of way are another possibility. Criteria for power plant siting must be accomplished by criteria and means for siting distribution systems to transmit energy from the power plant location to the urban centers where utilitization will occur.

2. Pipe Lines

Pipe lines have been utilized for the transmission of liquid and gaseous fuels since the initial laying of a pipeline from the northwest oil fields in Pennsylvania by the Tidewater Oil. Coal pipe lines have also been utilized but not to any extent in Pennsylvania, with the exception of local transfer within the collieries of coal companies. The least expensive method of transporting energy is by the utilization of oil pipe lines which can transport energy at approximately one-third the cost of coal pipe lines or integral trains or gas pipe lines.

If power generating stations are to be sited remote from urban centers the necessity to transfer low sulfur crude oil or residual oil by pipe lines has required the consideration of installing these lines overhead instead of the normal underground installation previously used. Since these lines are visible and under pressure, their impact upon the ecology has been questioned.

3. Unit Trains

Unit or integral trains have lowered the cost of coal movement by about forty percent, but at the present time their savings are limited to movement over one rail carrier's line only, with the additional problem of where rail mergers have occurred legal requirements cause an increase in cost since local union jurisdiction requires changing of crews. Integral trains are almost competitive with gas in transferring energy, as well as competitive with 500 to 700 KV overhead transmission. It should be remembered that integral or unit trains can be utilized to transfer liquid fuels as well as solid fuels. The success of the unit train has been limited due to the lack of sufficient hopper cars and the fact that the majority of mines are not equipped to store coal in a manner to efficiently load unit trains or to be able to inventory coal during shortages of hopper cars. Additional hopper cars are urgently needed.

If this means of energy transportation is to be developed to its ultimate, the financial condition of the railroad industry will have to be corrected, as very large commitments of capital funds will be necessary in order to permit the efficient utilization of unit trains for the transfer of coal within the Commonwealth. As the Commonwealth has a very well developed railroad network, the transfer of coal energy should be encouraged rather than utilizing alternate modes of energy transportation, which would of necessity consume additional land either by overhead transmission of electrical energy or overhead pipe line transfer of liquid fuels.

4. Impact on the Environment

Bulk transfer of energy in any form has some impact upon the environment. In the utilization of land for railroad rights of way, electrical power lines rights of way, or underground or overhead pipe lines for oil, coal, or gas, the least impact occurs by the utilization of proposed energy corridors developed in such a means to transfer the energy from its source to the urban centers of consumption. In the urban areas the least impact on the environment occurs by the utilization of underground distribution of energy. Presently, natural gas is distributed by underground pipe line and any new residential developments in the Commonwealth are receiving their electrical energy by underground cable distribution. Within the next ten to fifteen years most of the distribution systems of the electrical utilities will have been rebuilt and most will have been replaced with environmentally acceptable overhead or underground systems. As the energy demands increase in the urban areas, a network of transportation modes must be developed to deliver the energy as inexpensively as possible with the least impact on the environment. These two requirements may possibly require the siting of smaller power plants nearer the consuming center in order to limit the necessity to transport as much energy. These close-at-hand power plants might possibly be large centrally operated fuel cells, or could utilize pure hydrogen which would be pipe-lined to the urban centers from a large electrolizer adjacent to a nuclear power plant as proposed by Dr. Linden. The hydrogen would then be utilized in homes directly or in fuel cells at the urban center.

To help mitigate the problems of energy distribution, the present adversary legal system should be reviewed in order to enable the Commonwealth to distribute energy in a method acceptable to the environment in general, but not limited by individualistic complaints.

5. Centralized Heating and Cooling

The comfort conditioning of the occupied space of buildings utilized for commercial and residential use requires a uniform code for energy loss in the winter and gain in the summer by various zones within the Commonwealth in order to conserve energy. If conservation of energy is to be developed in this way, the delivery of the energy can also be optimized by the use of central heating and cooling where possible. This will permit the interchange of heat gain and heat loss which now results in considerable waste. The delivery of energy to such a central system can be made by any of the fuel sources; coal, oil, gas or electric. Environmental conditions of the central plant would be the determining factor in the type of fuel used.

The delivery of energy to individualized units in lower density areas would indicate the utilization of either oil, gas or electric. Environmental conditions ultimately will probably require some controls on oil-burning equipment. Gas and electricity should be more acceptable. The utilization of the heat pump in areas where the heating and cooling requirements would economically justify the additional capital cost is an additional way of reducing energy consumption by gaining heat from the outside air.

D. Assessment of Energy Needs for Transportation

Most of the background information for this section, particularly parts 1 and 2, were extracted from reference (2).

As the demands for petroleum fuels grow, they will have a severe impact on the transportation market where great reliance is placed on such fuels. The question of how best to use energy for transportation thus becomes a pressing one. The problem is complicated by the fact that energy requirements for transportation are expected to grow substantially in the years ahead (10) and that efforts to limit pollution emission from automotive vehicles (our major transportation mode at present) are resulting in less efficient utilization of fuels.

1. Energy Used in Transportation

Table VIII lists the amount of energy used for transportation as reported in reference (2). As shown in this table, approximately 29% of the Nation's Net Energy Input (NEI) is used for transportation. (Net energy input is defined as the Gross Energy Input minus that energy which is lost in generating electricity.) Reference (2) reports that 24% of the gross energy input is used for transportation.

Table VIII also shows that secondary transport-related activities such as fuel refining and manufacture of transportation equipment add another 9%, so that the total energy used for transportation activities rises to 38% of the NEI.

2. Efficiency of Various Transportation Modes

The efficiency of various modes of transportation is best illustrated by the amount of fuel used per passenger-mile or per ton-mile of freight. Generally, transportation modes with poor efficiency also emit the most pollutants per passenter-mile or ton-mile.

Table IX lists comparative energy requirements for various modes of passenger transportation. Examination of this table shows that trains and large busses are the most efficient for transporting passengers. Automobiles utilize four to eight times as much energy per passenger-mile and jet airplanes utilize about six times as much energy as fast trains and large busses. For freight handling, pipe lines, trains, and barges provide more than 200 ton-miles per gallon of fuel while trucks transport about 50 ton-miles per gallon.

3. Action Needed

Since transportation at present relies heavily on petroleum, the increasing shortages of such fuels have severe implications on the future of various transportation modes. To mitigate this situation several important steps must be taken:

(a) Greater use of rail transportation must be made both for freight and passengers. The railroads cannot be allowed to die. As a matter of fact, they must be improved. In the East, high-speed systems are needed. Where lines are abandoned, means must be developed to have the state get control of rights of way lest they be lost for future use.

(b) More electrification of railroads will be needed in the years ahead, especially in areas with high density traffic. Electricity-producing nuclear power plants thus might be used to augment the energy supply used for transportation.

(c) More efficient automobiles with low polluting characteristics must be developed. Development of electric cars for urban use must be accelerated.

(d) Where automobiles must be used for transportation to and from work, incentives for sharing of rides should be instituted.

(e) Interfaces between various forms of transportation must be improved to facilitate the flow of both passengers and freight.

(f) Improve urban mass transportation to reduce use of automotilbes and second and third car purchases.

TABLE IX

ENERGY FOR TRANSPORTATION IN QBTU's (QUADRILLION BTU's)

Sector	Use	(QBTU)	Total QBTU	% of Net Energy Input*
Primary Transport (propulsion)	Automobile	7.60		
	Truck and bus	3.06		
	Jet	1.63		
	Railroads	0.72		
	Marine	0.55		
	All other prop.	1.59	15.15	29%
Secondary Transport (related activities)	Fuel refining, asphalt and road oil, energy	2.42		
	Primary metals used in transport manufacture	1.02		
	Manufacturing	0.53		
	All other secondary	1.05	5.02	9%
Total				38%

* Reproduced from reference (2).

TABLE X

EFFICIENCY OF MODES OF PASSENGER TRANSPORT

Mode	Cruise Power (H.P.)	Speed (mph)	Seat Capacity (no.)	Occupancy Assumed (%)	Transportation Efficiency (Pass. mile per gal.)	Transportation Efficiency (BTU's per pass. mile)*
RAIL						
Fast train**	2,400	100	360	55	133	980
Commuter train+	4,000	40	1,000	50	100	1,300
Cross-country train	2,400	60	360	55	80	1,600
10-car subway train++	4,000	30	1,000	50	75	1,700
ROAD						
Large bus	200	50	43	58	125	1,000
Automobile (sedan)	50	67	4	25-50	16-32	8,100-4,100
AIR						
747-jet	60,000	500	360	55	22	5,900
707-jet	28,000	500	136	62	21	6,200
STOL# plane (4-prop)	10,000	200	99	55	18	7,200
SST (US)	240,000	1,500	250	60	13.7	9,500
Helicopter (3 engine)	12,000	150	78	58	7.5	17,300

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* Conversion obtained with 130,000 BTU's per gallon.

** 3-car, self-propelled, bi-directional double-deck, 67 tons per car.

+ 10-car train with 2 diesel locomotives, 950 tons gross weight.

++ New N.Y. subway train at heavy, non-rush hour traffic.

# Short-take-off-and-landing (see "Aircraft in the Balance," Environment, December, 1971).

Source: Rice, R.A., ASME, 70 WA/ENER-8, November 1970, Table 12.

Reproduced from Reference (2).

References Cited

(1) Gordon, Richard L., Professor of Mineral Economics, The Pennsylvania State University, Letter to N. J. Palladino, dated February 22, 1973.

(2) Grimmer, P. and Luszczynski, K., Lost Power, Environment, Vol. 14, No. 3, April, 1972.

(3) Smigel, Albert E., Comments on the Energy Problem, Bureau of Statistics, Research and Planning, Pennsylvania Department of Commerce, December, 1972.

(4) U. S. Atomic Energy Commission, 1972 Atomic Energy Programs.

(5) Yellot, John I., Solar Energy in the Seventies, The Bent of Tau Beta Pi, Vol. LXIV, No. 2, Spring, 1973.

(6) Krieger, James H., Energy: The Squeeze Begins, Chemical & Engineering News, Vol. 50, No. 46, November 13, 1972.

(7) McKetta, John J., et al, Report to the Secretary of the Interior of the Advisory Committee on Energy, June 30, 1971.

(8) McKetta, John J., Today's Energy Sources - Their Projected Life, Presented at Symposium for Industrial Users of Natural Gas - Mid-American Oil Company Forum, April 24, 1973, Houston, Texas.

(9) McKetta, John J., U. S. Warned About Energy Chaos, World Oil, Vol. 174, No. 7, June, 1972.

(10) Winger, John G., et al, Outlook for Energy in the United States to 1985, The Chase Manhattan Bank, Energy Economics Division, June, 1972.

(11) Grundeman, Frederick D., Report from the Governor's Office of State Planning and Development on Pennsylvania Energy Consumption Forecasts, June 25, 1973.

(12) Edmunds, William E., Coal Reserves of Pennsylvania: Total, Recoverable, and Strippable, Information Circular 72, Commonwealth of Pennsylvania, Department of Environmental Resources, Bureau of Topographic and Geologic Survey, 1972.

(13) Preliminary Recommendations of the Workshop on R & D Priorities in Pennsylvania, March 5, 1973, Center for the Study of Science Policy, Institute for Research on Human Resources, The Pennsylvania State University.

(14) Proceedings of the Governor's Briefing on Coal Conversion Processes, January 25, 1973, Harrisburg, Pennsylvania, Bureau of Scientific and Technological Development, Pennsylvania Department of Commerce.

(15) Proceedings, Pennsylvania Coal Conference, April 4, 1974, Pittsburgh, Pennsylvania.

(16) Szego, G. C. and Kemp, C.C., Energy Forests and Fuel Plantations, Chemtech, May 1973.

(17) Bureau of Mines Energy Programs (1971), IC 8551, Bureau of Mines Information Circulator/1972, United States Department of the Interior.

(18) Engineering for Resolution of the Energy-Environment Dilemma, Report of the Committee on Power Plant Siting, National Academy of Engineering, Washington, D. C.

(19) The Potential for Energy Conservation, A Staff Study Office of Emergency Preparedness, October 1972.

(20) Chapman, Howard, W., Associate Deputy for Air, Water, and Community Protection, Pennsylvania Department of Environmental Resources, Ecological Constraints on Fuel Uses, presented at the Pennsylvania Industrial Fuel Efficiency Seminar, Harrisburg, Pennsylvania, August 22, 1973.

(21) Let's Talk About Energy Consumption, a Pamphlet Produced by the Oklahoma Gas and Electric Company.

(22) Statistical Benchmarks for Energy in Pennsylvania, Pennsylvania Department of Commerce, Smigel, A. E. - Release No. S-4-74.

(23) Electric Energy Demands for Pennsylvania - How Much When? - Smigel, A. E., Krawiec, F. - Wharton Quarterly, Winter 1973

References Used in Section V but not Cited

(1) Anonymous. 1972. The Demand for Energy and Appalachia's Coal. Appalachia 5(4): 1-53.

(2) Chamber of Commerce of the United States. 1972. Meeting the Natural Energy Needs.

(3) Committee on Power Plant Siting. 1972. Engineering for Resolution of the Energy-Environmental Dilemma. National Academy of Engineering.

(4) Federal Power Commission. 1971. The 1970 National Power Survey. Washington, D. C.

(5) Hottel, H. C. and J. B. Howard, 1971. New Energy Technology. Some Facts and Assessments. Mass. Institute of Technology.

(6) Milz, E. H. and D. E. Broussard. 1972. Technical Capabilities in Offshore Pipeline Operations to Maximize Safety. Offshore Technology Conference, Dallas, Texas.

(7)) Patrick, R. 1972. The Potential of Various Types of Thermal Effects on Chesapeake Bay. Journal Washington Academy of Science, 62(2): 140-144.

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